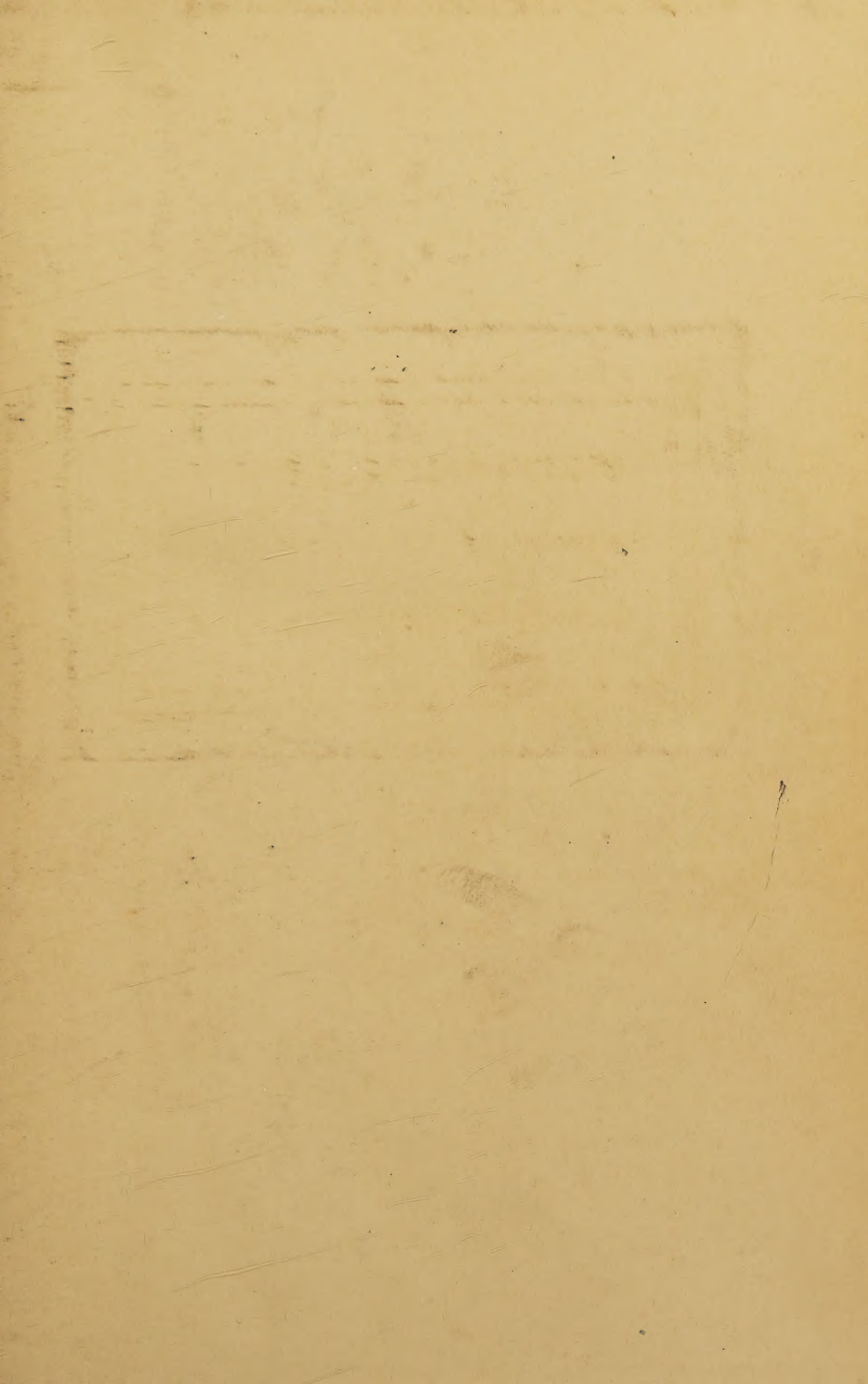


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AVIATION MEDICINE

AVIATION MEDICINE

BY *e*

LOUIS HOPEWELL BAUER, A.B., M.D.

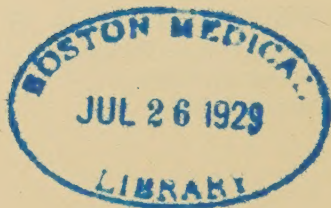
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TO
EDWARD C. SCHNEIDER, PH.D., SC.D.

A PIONEER IN AVIATION PHYSIOLOGY

THIS BOOK IS DEDICATED

AS A TOKEN OF

FRIENDSHIP AND ESTEEM

PREFACE

Aviation medicine is a new subject. The bibliography is constantly growing, but it consists chiefly of short articles on the individual phases of the subject. So far as known, this is the first book written on this subject in America, and the first one written anywhere since the war. Consequently, it will probably receive considerable criticism.

The author claims little in the way of originality. An attempt has been made, however, to consider all phases of the subject, to correlate the results of various workers and to present a handbook for the

CORRECTION

Preface, page vii, line 3, "book" should read "textbook"

way, and that it will stimulate interest in the subject among physicians in general. Attempt has been made to make the book sufficiently technical to be of use to the Flight Surgeon, but not too technical to interest the physician who has not worked in the subject. The presentation is, naturally, chiefly from the American viewpoint, but the work in other countries has received consideration also. Some of the opinions expressed are the personal views of the author and do not necessarily represent the viewpoint of the Medical Section of the United States Army Air Service as a whole.

The newest of the medical specialities, aviation medicine, has made great progress and has a future of untold possibilities.

The author is deeply indebted to many of his associates at the School of Aviation Medicine for assistance, valuable criticisms and suggestions. He is especially indebted to Prof. Edward C. Schneider who has given many suggestions and criticisms, and who has reviewed nearly every chapter. The section of physiology is based to a large

extent on his work. In fact, nothing could be written on the physiology of altitude without quoting him largely.

He is also indebted to Major R. F. Longacre for extensive use of his paper on "Personality Study."

He also wishes to express his thanks to Major Francis H. Poole for suggestions in the chapter on "Neuropsychic Considerations;" to Capt. Charles A. Pfeffer for criticism of the chapter on "The Eye in Aviation;" to Capt. Harrison H. Fisher for suggestions relative to the chapters on "The Selection of the Flyer;" to Capt. William C. Munly for suggestions and criticisms of several chapters; to Miss Dorothy Truesdell for assistance with the bibliography, transcripts of literature and for secretarial work; to Mr. Jules K. Sindic for preparation of the illustrations; to Miss Geneva Croxford and Miss Elizabeth K. Stark for assistance with the preparation of transcripts from the literature; and to Miss Helen I. Hambler for typographical work.

L. H. BAUER

The School of Aviation Medicine
June, 1925

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INTRODUCTION

It is probable that man has had the desire to fly ever since the beginnings of the human race. We read of attempts to fly both among mythical and actual characters of history. Balloon ascents were among the earliest attempts in aviation. The flight of Glaisher in 1862 and of Tissandier in 1875 are quoted in the section on altitude. The earliest flight ever made by a heavier-than-air machine was at Quantico, Va. by Langley's steam driven aerodrome, on May 6, 1896. The first real successful flight, however, involving transportation of the pilot was made by the Wright brothers on December 17, 1903. The distance that the plane flew was 852 feet. From then on aviation developed gradually and slowly. The airplane was very much in its experimental stage at the beginning of the world war. The urge of necessity called for new means of warfare resulting in rapid progress throughout the war and this progress has continued up to the present time. We now have heavier-than-air planes from the size of the diminutive Sperry Messenger to that of the gigantic Barling Bomber, which weighs 26 tons unloaded. On the lighter-than-air side we have as a development from the balloon the huge dirigible airships such as the Shenandoah and the Los Angeles.

Aviation has become a commercial proposition as well as a military one. Passenger and freight lines are numerous in Europe and are slowly being developed in the United States. In 1921, French commercial airplanes carried over 10,000 passengers and over 175,000 tons of baggage and mail with an efficiency of 97 per cent. The United States Air Mail Service is now carrying mail from New York to San Francisco as well as over shorter distances with remarkable efficiency. Planes have been developed for every type of work; speeds formerly thought impossible have been accomplished; and man has ascended to altitudes never before dreamed of.

Up to the time of the world war, efforts were directed solely toward developing the mechanical efficiency of the plane. Little thought was given to the pilot. Flying was considered to be purely a case of courage; in other words if a man had the nerve to fly there was no reason why he should not fly. Bitter experience has taught us other-

wise. Man has become adapted over centuries of existence to a terrestrial environment. As a result of modern aviation he is now subjected to a new and rapidly changing environment and one calling for quick decisions. He calls into play physical factors which he did not know that he had. He travels at terrific speeds, and he has to compensate to the diminished oxygen of high altitudes, to intense cold, to violent winds, to intense glare and to marked disturbances of his equilibrium. He is subjected to conditions which are markedly fatiguing not only from a physical standpoint but also from a mental and nervous standpoint. It was soon found that not every one could fly. It has been stated that the British found, during the first year of the world war, that of every hundred aviators killed, two met death at the hands of the Germans, eight because of defective planes or motors and ninety were killed due to their own individual deficiencies. Of these ninety, sixty were found to have been due directly to physical defects. As a result of this startling discovery, the British established a special Care of the Flyer Service and their aviators were selected with due regard to their qualifications. As a result, at the end of the second year, their fatalities due to physical defects were reduced from sixty to twenty, and at the end of the third year a still further reduction had been made from twenty to twelve.

Practically every country now requires a special physical standard for its aviators. An immense amount of research has been carried out, as a result of which we are now able to state which man should fly and which man should not. Consequently, a new medical specialty has arisen which has become known as aviation medicine. This specialty involves a knowledge of physiology and medicine, of ophthalmology and otology, of psychology, neurology and psychiatry. Each of these specialties has a distinct application to aviation. A specialist in aviation medicine has become known in the United States as a flight surgeon. He examines men and selects those fit to fly. He classifies them as to their ability to withstand the effects of altitude and, finally, he maintains medical supervision over them in order to keep them in a condition fit to fly. As a result, many lives are saved and accidents are becoming less frequent.

The amount of research which has rendered all this possible has for the most part been carried out in the last ten years. It is doubtful if any branch of medicine has made as great a progress during the same period as has aviation medicine. Beginning from nothing, it has developed to its present status of a distinct medical specialty.

In the chapters which follow an attempt has been made to discuss in detail the factors involved in flying. Points to be considered in the selection of the flyer have been taken up first. Next the effects of altitude, cold, wind and speed are discussed and an altitude classification test has been described. Finally, the care and maintenance of the flyer are considered and the steps necessary to keep him in a fit condition for flying are outlined.

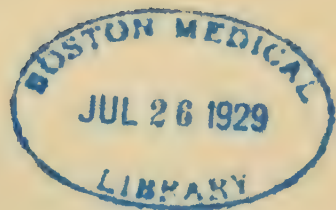
The bibliography of aviation medicine is becoming larger daily and the medical world at large is beginning to take an interest in the subject.

As the development of aviation progresses, the medical profession must keep pace with it. Flying even yet is only in its infancy, likewise aviation medicine is only beginning.

Too much credit cannot be given to the early workers in this subject who, having little to begin on, created a structure on which our present specialty has arisen. To mention only a few of these whose work has been of infinite value to aviation there are, Schneider, Henderson, Dunlap, Watson, Wilmer, Berens, Whitney, and Jones among the Americans; Dreyer, Flack, Birley, Haldane and Anderson among the British; Camus, Nepper, Garsaux, Cruchet, Moulinier, Maublanc, Ratié, and Beyne among the French; Gradenigo, Herlitzka and Aggazzotti among the Italians. Added to these were many others whose work was only of less importance. Since the war the work has been carried on by the efforts of some of these and many other workers, many of whose achievements are discussed in the following pages. Schools of aviation medicine or air service research laboratories exist in the United States, England, France and Italy.

England and Italy have independent air forces with special air medical services. France has a semi-independent air force with special personnel attached for medical advice. The United States Army has a representative of the Surgeon General in the office of Chief of Air Service and a number of officers who have received training at the School of Aviation Medicine are detailed as flight surgeons with the various Air Service units. The future possibilities of aviation medicine are boundless.

SECTION I
THE SELECTION OF THE FLYER



CHAPTER I

GENERAL PHYSICAL QUALIFICATIONS

In this chapter we shall confine ourselves to a discussion of the general physical qualifications, essential in a flyer. In the later chapters we shall discuss the more special qualifications.

HISTORY

First of all, a medical history should be obtained. Among the things especially to be inquired about is rheumatism —particularly, acute articular rheumatism (rheumatic fever). A history of this should lead one to suspect the presence of organic heart disease. A history of recent attacks of malaria should be considered as disqualifying, because the cold incident to high altitude flying causes a recurrence of the malarial attacks. This is, of course, particularly true in the aestivo-autumnal type, where a cure is always more or less uncertain. A history of hay-fever, we formerly considered as disqualifying but now we no longer do so. Hay-fever according to the layman is often something else than true hay-fever. Hence, the history is not to be relied upon. Furthermore, the author has never yet seen a case of hay-fever that was not benefited by flying. On the other hand, asthma, which frequently follows, or is associated with hay-fever, is disqualifying, as it means a restriction of breathing. A history of syphilis is also disqualifying. Syphilis is too treacherous a disease with which to take chances. The possibility of onset of cerebral symptoms is a special danger. A history of tuberculosis is not necessarily disqualifying, but should lead to a very careful physical examination. The presence of activity is disqualifying. Injuries should be carefully gone into. A history of injury to a bone or joint should cause a careful functional examination to be made of the part involved. A history of injury to the head accompanied by unconsciousness should usually be considered as disqualifying. However, if there be no history of fracture and there has been a complete absence of symptoms since the injury, it may be disregarded. Inquiry should also be made as to history of gonorrhea, tonsillitis, scarlet fever,

pneumonia, influenza, and typhoid. The history alone of any one or more should not disqualify, but should lead to careful examination to determine whether or not they have left conditions which do disqualify. So called influenza may prove to have been encephalitis which will be considered in a later chapter. A history of empyema should usually disqualify. It certainly should if there be marked adhesions or a partial collapse of the lung. An empyema which leaves no reduction of lung mobility or function may be passed.

The history of diseases of the eye, ear, nose, throat and nervous system are taken up in the appropriate chapters.

AGE

The age of the flyer is one that has received much attention. During the war it was pretty generally agreed that flying was a young man's game. The optimum age was given as from twenty to twenty-four years. Our experience has since modified that view somewhat.

Unquestionably, those under twenty, while they may learn to fly easily, lack judgment, and are not to be recommended. The optimum age is increased somewhat. It is believed we can give it as from twenty to twenty-eight years. However, many men have learned to fly after that age, but it is doubted whether good combat flyers are ever developed from men who start their flying when over twenty-eight. It is not believed that a man should take up flying after thirty-five, except perhaps in the cases where it is desirable for him to learn to fly for administrative information.

When we come to the question of the age to which a good flyer will last we have reached a debatable point. Any statement made is bound to arouse a storm of criticism. Personally, the author does not believe flying has gone on long enough for us to make any hard and fast rules. Unquestionably, it is going to depend largely on the individual. A flyer who has good eyes, is sound physically, who has good nervous stability, and who takes care of himself, will last a good many years. On the other hand, the one who has only fair nervous stability and who does not take care of himself, will last but a few years.

The effects of age on the eyes, the cardiovascular system, and the nervous system, the development with age of a marked conservatism, result in making flyers unfit for flying at a much earlier age than the same factors render ground officers unfit for their duties. There are bound to be exceptions to all rules, but the author ventures the state-

ment that few flyers over fifty years of age will ever be found flying their own planes. A large number will not last that long. Combat work should be restricted to those not over thirty or thirty-five.

A few years ago, the statement was frequently made that the flyer would not last more than ten to fifteen years. In the case of the flyer with a sound makeup, who takes good care of himself, that limit may be extended, but in the cases of others, there would seem to be no grounds for extending it.

We come now to the actual physical examination.

TABLE 1
Standards for all applicants except Filipinos

A STANDARD ACCEPTED MEASUREMENTS				B THE FOLLOWING VARIATIONS FROM THE STANDARD SHOWN IN COLUMN A ARE PERMISSIBLE WHEN THE APPLICANT IS ACTIVE, HAS FIRM MUSCLES, AND IS EVIDENTLY VIGOROUS AND HEALTHY			
Height	Weight	Chest measurement		Height	Weight	Chest measurement	
		At expira- tion	Mobility			At expira- tion	Mobility
<i>inches</i>	<i>pounds</i>	<i>inches</i>	<i>inches</i>	<i>inches</i>	<i>pounds</i>	<i>inches</i>	<i>inches</i>
64	128	32	2	64	120	30	2
65	130	32½	2	65	121	30	2
66	132	32½	2	66	122	30½	2
67	136	33	2	67	124	30½	2
68	141	33½	2½	68	126	30¾	2
69	148	33½	2½	69	128	31	2
70	155	34	2½	70	130	31½	2
71	162	34½	2½	71	133	31¾	2
72	169	34¾	3	72	138	32½	2½
73	176	35½	3	73	143	32¾	2½
74	183	36	3	74	148	33½	2½
75	190	36¾	3½	75	155	34½	2¾
76	197	37½	3½	76	161	34¾	2¾
77	204	37¾	3½	77	168	35½	3
78	211	38½	4	78	175	35¾	3

GENERAL BUILD

In modern airplanes, the height and weight of applicants are not of great importance. An obese type of individual, is, however, not fitted for flying, because, he has difficulty on account of lack of room in the cockpit, and because of his build he is apt to have a neuro-circulatory disturbance. Height, weight and chest measurements should be in proportion. The physical standards for commission or

enlistment in the United States Army are equally applicable to the Air Service. For this standard, which is taken from the United States Army regulations (7)¹ see table 1.

Mobility of the chest is important. There must be nothing to interfere with free breathing, for at high altitude the flyer compensates in part by increased volume of respiration.

RESPIRATORY SYSTEM

Respiratory conditions are changed in the air from those found on the ground. There is a constantly decreasing barometric pressure, resulting in a decreased partial pressure of oxygen, diminishing temperature and in most planes a strong blast from the propeller. The cold and the wind blast make breathing more difficult. The increasing altitude calls for deeper breathing. There are added the effects of fatigue and excitement. Hence if there be any obstruction to or difficulty in breathing, we shall find cyanosis and dyspnoea developing.

In general, it may be said that any condition that interferes with respiratory function should disqualify. Chronic bronchitis, emphysema, asthma, pleurisy, active pulmonary tuberculosis and inactive pulmonary tuberculosis of such extent that future trouble is probable, are all to be considered as disqualifying. They mean a reduced lung function and activity. Pleurisy even though no symptoms are present at the time of the examination is prone to recur and is usually tubercular in origin. Acute respiratory conditions should disqualify temporarily and a reëxamination should be made when they subside.

In the examination of the respiratory system, not only should the usual methods of physical diagnosis be employed, but advantage should be taken of the X-ray and the fluoroscope. In all doubtful conditions an x-ray plate is of great value in reaching a final decision.

THE CARDIOVASCULAR SYSTEM

The cardiovascular system is very important in aviation. Fatigue, stresses, high altitude, all produce considerable strain on this system. Consequently, we must select a man who has a responsive, elastic system, capable of compensating for the strain it will encounter.

The effects of altitude on the cardiovascular system will be left until

¹ Numbers in parentheses refer to list of references at end of chapter.

we take up the subject of altitude, but it may be said here, that high altitude affects the pulse, the blood pressure and the heart. Different individuals react differently.

Two of the most important points to look for are organic heart disease and vasomotor instability.

Organic heart disease should disqualify. The circulatory mechanism is under too great a strain to permit a man with even a compensated organic lesion to fly. The two most important valvular diseases are, of course, mitral stenosis and aortic regurgitation. Care should be taken to distinguish functional from organic murmurs. As a general rule a systolic murmur unaccompanied by any cardiac enlargement or other signs of heart disease may be disregarded.

Sinus arrhythmia and extra systoles may be disregarded, but all other arrhythmias should be rejected as they are of pathologic significance. More will be said about arrhythmias when we come to the subject of altitude.

Pulse rate. It is a question of how much significance the pulse rate really is. Anderson (2) claims it is of no significance. As a general rule, however, a sitting pulse rate of over 100 indicates (conceding that organic heart disease has already been eliminated), vasomotor instability or thyroid disease. Of course, we find cases, particularly among those who are taking their initial examination, in which the high pulse rate can be accounted for by nervousness. These can, with a little care, usually be detected. Vasomotor instability is, however, a serious condition in the flyer. The symptoms are high pulse rate, poor exercise tolerance, cold extremities, sweating, and breathlessness on exertion. This will be taken up more in detail in the third section of the book. The flyer's subjection to cold, fatigue and low oxygen are all strains on the vasomotor mechanism and those who show instability are poor risks. Not infrequently a high pulse rate indicates a lack of exercise and a period of outdoor exercise will overcome it. Careful examination should be made to detect enlargement of the thyroid. Look also for high pulse rate, tremor and emotional instability, in suspected thyroid disease.

It is becoming more and more apparent from the conflicting statements in the literature that we know little or nothing about blood pressure from a physiological standpoint. However, from the standpoint of aviation we can say this—that a man with a high blood pressure withstands altitude at the expense of considerable strain. For this reason, it is believed that candidates with a systolic blood pressure

above 145 mm. Hg should be rejected. If the blood pressure is found only moderately above this point, repeated examinations should be made to ascertain definitely that it is not a transient condition.

If the systolic blood pressure is found to fall instead of rising on change of posture from reclining to standing it is also a sign of vasomotor instability. If all cases of doubtful vasomotor instability a circulatory efficiency test will be of value in reaching a final decision as to qualification of the candidate. Of all the tests so far described, it is believed the one devised by Schneider (4, 5) is the most useful.

Schneider's test is based on six factors: (a) the reclining pulse rate, (b) the standing pulse, (c) the difference between the reclining and standing rates, (d) the difference between the standing rate and the rate after a standard exercise, (e) the length of time it takes for the exercise rate to return to the normal standing rate, and (f) the difference between the reclining and standing systolic blood pressures. Each factor has a maximum value of three points. The total score may, then, be anywhere from a maximum of 18 to a minimum of -11. Roughly speaking, an index of 14 to 18 is excellent; 11 to 13 is very good; 9 to 10 is fair; 7 to 8 is doubtful; and below 7 is unsatisfactory. The method of performing this test will be found in the supplement at the end of the book. There are certain factors to be taken into consideration in connection with the interpretation of the findings on the test. It should not be performed within two hours after a meal, as the ingestion of food materially lowers the score. The amount of habitual exercise, the amount of smoking, amount of sleep all affect it to a certain extent and should be taken into consideration. The index in any individual varies during the 24 hour cycle, and also varies with the physical feelings of the subject. It is most valuable in checking up the condition of a flyer on whom a number of indices have previously been performed. His normal index being known, it forms a basis for comparison.

The condition of the blood vessels should also receive attention in any cardiovascular examination. The arteries should be soft. Evidences of sclerosis should disqualify the candidate as such individuals do not wear well. Varicose veins, if of any extent should disqualify. They mean poor circulation, and this added to the cold the flyer has to endure will interfere with the function of his legs.

BONES AND JOINTS

Examination of the bones and joints should be made in detail. Setting up exercises are an excellent method of determining mobility and function. The flyer must have full mobility of the upper extremities; at least 75 per cent mobility of the knee joint; 50 per cent mobility of the ankle joint and complete mobility of the hip joint. The faster and lighter planes require more mobility in their manoeuvring than do the heavier planes such as seaplanes. Anderson (2) states that a man can fly a seaplane if he has an artificial leg. However, except in war time, when economy of personnel may be an urgent factor, it would seem unwise to qualify such an individual, even for limited service. Flat feet, even second degree, is not disqualifying.

SKIN

Contagious diseases of the skin, should, of course, disqualify until cleared up. Marked acne vulgaris and psoriasis, while they do not interfere with flying, are undesirable, because they have an unfavorable psychological effect on the subject's associates. This is particularly true if men are quartered in barracks.

DIGESTIVE SYSTEM

In examining the digestive system, one should take note of the tone of the abdominal musculature. Poor muscular tone usually means ptosis and splanchnic dilatation. Hyperacidity and other functional disturbances are frequently associated with nervous instability and should be considered in connection with that. Organic diseases of the digestive tract mean a lowered vitality and resistance and hence should disqualify. In connection with the digestive system, the teeth should be carefully examined. Roots or decayed teeth should be regarded as probable sources of infection and should be removed before acceptance of the candidate. Crowns are to be looked upon with suspicion and the roots should be x-rayed. Frequently, rejection on account of the teeth need be only temporary, until the proper dental work has corrected the defects.

HERNIA

Hernia is a cause for rejection, as there is too much danger of incarceration or strangulation. A successful operative cure of a hernia

removes the disqualification. There is considerable muscular effort involved in flying the heavier types of planes, particularly on a "bumpy" day.

GENITO-URINARY SYSTEM

The presence of focal infections or of venereal disease is disqualifying. Syphilis has already been considered under history. Gonorrhea is disqualifying not only because of the local and constitutional effects of the disease but because of the mental worry accompanying it. This applies to all venereal disease. Worries as will be seen when we come to discuss the neuropsychic factors, have a bad influence on the flyer.

Diseases of the kidneys or bladder should disqualify. They are serious conditions, they produce constitutional effects, are apt to become chronic and they weaken the vitality and resistance of the individual. If the examination of the urine shows the presence of sugar it should disqualify. If albumin and casts are present, disqualification should also follow. If albumin is present without casts, an attempt should be made to determine whether or not the albuminuria is orthostatic or due to local infection. A good general rule, is, that if the urine after once showing albumin, but no casts, is albumin free on three consecutive days, the candidate may be qualified. The flyer is subject to fatigue and cold. Either one, let alone both, are bad factors for kidney disease. It is safer, therefore, to insist on sound kidneys.

In conclusion, then, in selecting a candidate for aviation, we want a young man of good history, with good build, sound heart, lungs, kidneys, good musculature, good vasomotor control, and who has complete freedom of movement.

Practically all writers on the subject agree with the above statement. Anderson (2), Maublanc and Ratié (3), Sutherland (6), the writers in the Air Service Medical (1) and a number of others are all in accord.

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CHAPTER II

THE EYE IN AVIATION

That good eyes are one of the most important factors in aviation is agreed upon by all writers on the subject of aviation medicine and by nearly all aviators. Berens (1) states that 80 per cent of the pilots questioned at Issoudun gave the eye as the most valuable asset of the pilot. The sighting of other planes, distinguishing their colors and insignia, the judgment of distance, focusing far to near and back again, reading of instruments and maps, and so on, are all of vital importance to the flyer. Berens (1) in the same article states that one officer made the following statement:

The safety and proper execution of the work of a chasse-pilot depend entirely upon his vision. As one approaches the lines he immediately tries to locate, in his mind, all machines and patrols in his sector. The most effective means of accomplishing this is by dividing the sky into four divisions: (1) Left side, above superior wing; (2) left side, beneath inferior wing; (3) right side, above superior wing; (4) right side, below inferior wing. The clearing of these areas is best accomplished by gazing without attempting to focus on any definite point. If a machine is located it will appear as a mere speck and one must focus on it immediately. The pilot now looks: (1) above, (2) below, (3) right, and (4) left, still carrying the focus of the first machine. He bears the location of this plane in mind while clearing the other areas in the same manner. The position of the sky covered by the wings and fuselage must be uncovered by movements of the plane. Blind spots, caused by the superior and inferior wings of the same side, are cleared by throwing the machine into a virage in the opposite direction. This lifts the wing, and one may see above and below. At this same moment, while the machine is in the virage the pilot, by turning his head, may clear the sky behind and under the tail. He then virages in the opposite direction, thus clearing the blind spots on the other side. The chasse-pilot should continue these movements during the entire patrol, allowing no blind spot to be covered over forty-five seconds.

VISUAL ACUITY

The first factor to be discussed is that of visual acuity. In the United States, we believe that a standard of 20, 20 vision (that is, ability to read at 20 feet the letters supposed to be read at 20 feet) in each eye according to the Snellen test charts is not too high, and this

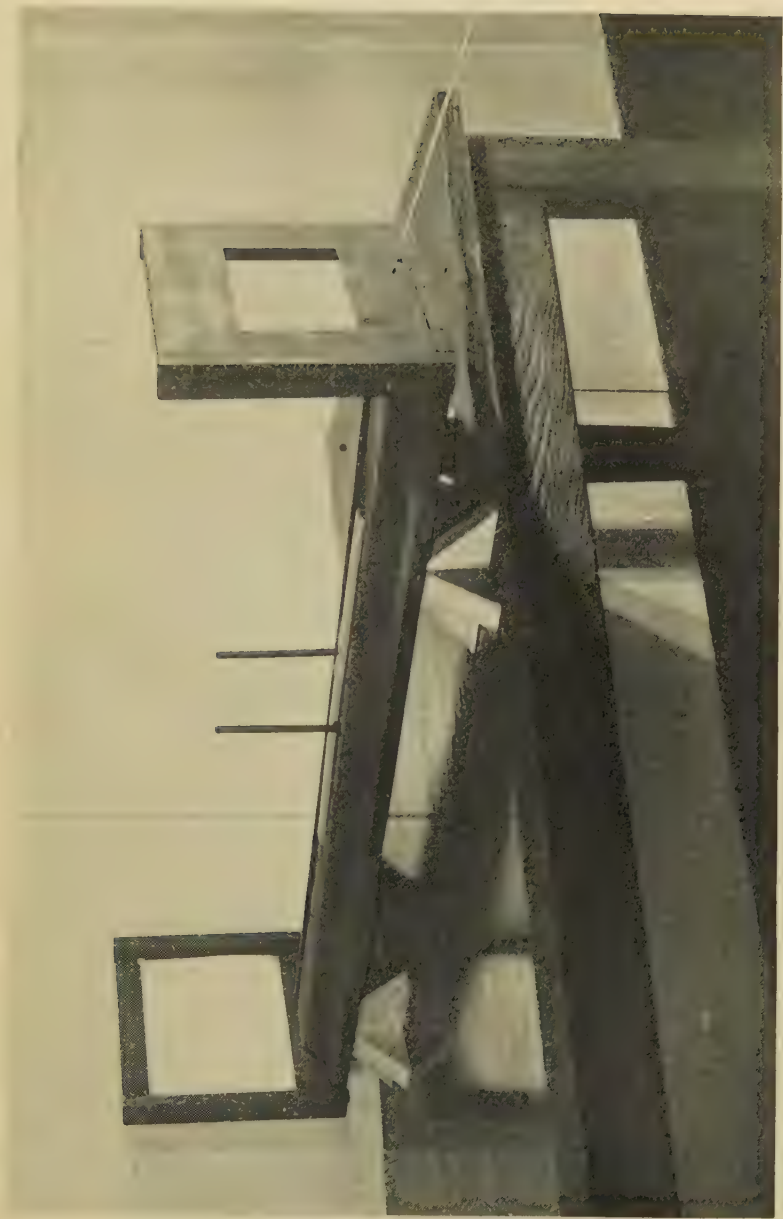


FIG. 1. THE HOWARD-DOLMAN DEPTH PERCEPTION APPARATUS



FIG. 2. TESTING DEPTH PERCEPTION
The subject is seated 20 feet distant from the rods

is the requirement for all those who are candidates for a pilot school. In the case of a flyer who is already trained, a standard of 20/30 may be accepted as satisfactory. In the case of an observer a standard of 20/50 is satisfactory, provided his vision can be, and is corrected to 20/20.

With any goggle at present available, it is not believed that a correcting lens is satisfactory in the case of a pilot. Correcting lenses restrict the field of vision. The distortion of the edges of the field by a prismatic effect of the goggles, the danger of their coming off or being broken are all too great to permit corrections to be used by the pilot.

Vision is apt to become worse and to accept a candidate for training who has vision less than normal is to invite trouble. He will have difficulty in learning to fly. In the case of the trained pilot whose vision has become less than normal we have a different situation. His experience allows him to compensate for his defect.

The question is often raised about the comparative efficiency of the man with 20/30 vision in one eye and 20/20 in the other, and the man with 20/30 vision in each eye. In our opinion at the School of Aviation Medicine, the man with 20/30 vision in each eye is the better man. His ability to judge distance will practically always be found to be better than that of the man whose vision is defective in one eye only.

JUDGMENT OF DISTANCE

This brings us to a consideration of depth perception or the ability to judge distance. A pilot is constantly being called upon to judge distance. He does so particularly when leaving the ground, when flying in formation and again on landing. In the last mentioned instance, levelling off too soon, too late, or misjudging distance from trees, buildings or other obstructions may be fatal.

Judgment of distance, or perception of relief or perspective is only accomplished by the two eyes. Binocular vision is therefore essential. Visual acuity, muscle balance, size of retinal image, etc., all play a part, but the basic factor is the binocular parallax angle. What is meant by this angle will be made clear by a diagram. Various tests have been used to determine this ability. During the war the old-fashioned hand stereoscope was used. This was a subjective test and it required a certain knack to perform which bore no relation to the actual ability of the candidate to judge distance. In 1919

Howard (11) devised a depth perception apparatus which was later modified by Dolman. Briefly, this consists of three sides of a box, the back, the bottom, and the front. The front and the back are 58 cm. high and 75 cm. wide. The floor 75 cm. wide and 55 or 110 cm. long. The box is painted black except that the anterior surface of the back is covered with white cardboard. In the middle of the front is cut a window 20 cm. wide and 12 cm. high; the upper margin is 38 cm. from the top. Two rods, also black, 1 cm. in diameter and

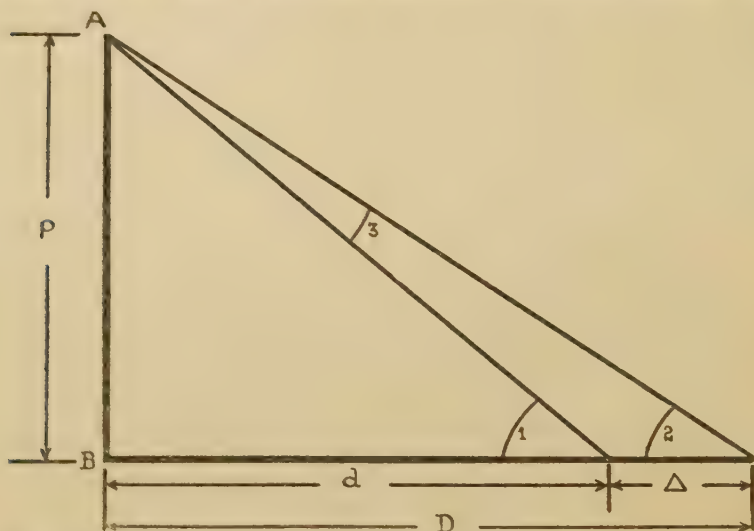


FIG. 3. DIAGRAMMATIC REPRESENTATION OF THE BINOCULAR PARALLACTIC ANGLE

(After Howard); d = distance to near object; D = distance to far object; $D - d = \Delta$ or difference in distance or depth distance; p = interpupillary distance; A and B = the two eyes; Angle 1 - Angle 2 = Angle 3 or the binocular parallactic angle.

26 cm. long are placed, one stationary in the middle of the floor from front to back and 2 cm. from the middle right to left. The other rod is placed on a sliding base controlled by a pulley so that its position is also 2 cm. from the center of the floor right to left and adjustable in the direction front to back. A scale in millimeters is arranged along the middle of the floor. The subject sits 20 feet away and looks at the rods through the window in the front end of the apparatus, his head being kept steady. The box is illuminated from above by a light reflected against the white back. He is given a view

of the rods when side by side the same distance from him. Then the adjustable rod is pulled forward or back and he is told to readjust it by means of the pulley until the two rods again appear side by side. The reading is then taken on the scale. The test is repeated twice or if there is a marked difference in the three readings, ten are taken and the average reading is taken as his depth perception. This reading should be not more than 25 mm. in the candidate for aviation and not more than 30 mm. in the trained pilot. This figure has been determined as a result of Howard's experimental work and our own practical experience.

That depth perception depends on binocular vision has been shown by this very test. In 100 cases examined at the School of Aviation Medicine by Palmer, the results were reviewed statistically by Deyo (6) and it was found that the average depth perception of persons regardless of vision was 18.6 mm. with both eyes and 118 mm. with either eye alone. With a vision of 20/20 in both eyes the average depth perception in 16 cases was 28.1 mm. If the vision was 20/15 in both eyes, the average depth perception was 12 mm.

The English, the French and the Dutch have an apparatus similar to ours except that they use three rods or wires, the middle one being adjustable. In the English test, the wires are about 2 mm. in diameter. In the French test, the rods are white against a black background. In both, the window in the front end is smaller than is the case in the American apparatus.

Spearman (14) of England has described an apparatus for testing judgment of distance which is on the principle of the above apparatus, but somewhat different. There is a board similar to the floor of the depth perception apparatus. Two milk glass plates are set in blocks, one of these plates is fixed in position, the other is movable as is the case with one of the rods in the depth perception apparatus. Behind each glass plate are electric lamps which illumine the plates. The subject sits 10 feet distant from the forward end of the board. Between the subject and the board at a distance of 2 feet from the front of the board is placed a screen 15 inches square. The screen has an aperture in its center $1\frac{1}{2}$ inches high and 3 inches broad. One plate is fixed 16 inches from the back end of the board, the board being 19 inches long, and the other plate is set in any position. The screen permits the view of only a portion of each plate. The only edges of the plate visible are the two vertical edges near the center of the board. By means of a pulley, the subject endeavors to place

the two vertical edges of the two plates at equal distances from him. A limited time is given for the judgment.

Another method for performing the test is to set one plate at different distances front or back of the other plate and to tell the

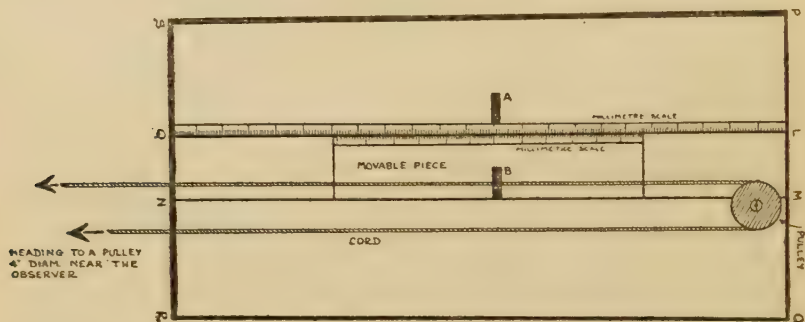


FIG. 4. SPEARMAN'S STEREOSCOPE

A and *B* are the blocks in which the milk glass plates are set

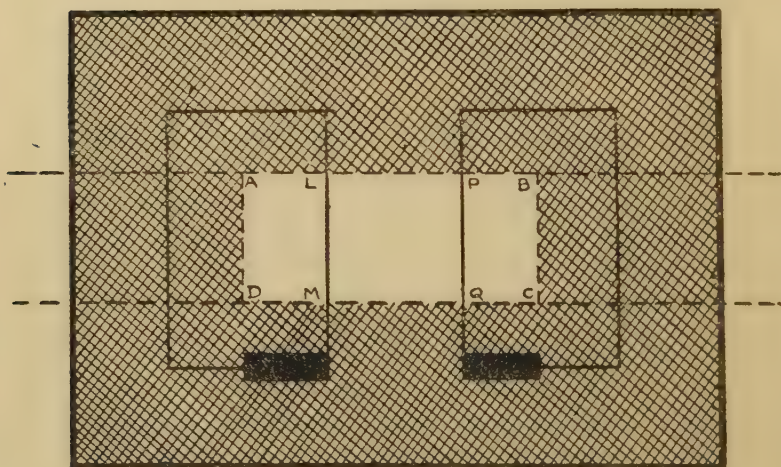


FIG. 5. SPEARMAN'S STEREOSCOPE

A B C D is the opening in the screen. *L M P Q* are the edges of the milk glass plates seen through the opening in the screen.

subject to state which plate is the nearer to him. Judgment can be complicated by setting the plates inclined to one another at an angle. Still a third form of the test is to have one plate moved at any



FIG. 6. TESTING THE FIELD OF VISION FOR FORM AND COLOR WITH THE PERIMETER

required rate by means of a motor. The other plate moves in a direction slightly divergent from this. The subject is told to try to keep this plate the same distance away as the other all the time.

The time element in depth perception is undoubtedly important. The British allow a maximum of twenty seconds for a reading. There is no time element in the American test, but it would seem wise to adopt one as the man who can judge accurately and rapidly is certainly better than the man who judges slowly even though accurately.

The American test has proved its usefulness from the practical standpoint. Our best flyers invariably do well on this test. The man who is rated as the best flyer in the service has a depth perception of 3 mm. It checks up with the pilot's ability practically always. In staleness, which will be taken up later, one of the early symptoms is a falling off in depth perception. The pilot is found to be making poor landings.

Care should be taken in giving the test to see that the subject does not move his head from side to side and to prevent his moving the adjustable rod from the front to the back of the box before adjusting it, as this will give him information as to the length of the box. If allowed to do this he can roughly estimate where the middle of the box is. He should be required to adjust the rod from the position in which it is placed.

PERIPHERAL VISION

Peripheral vision is very important to the pilot, as he must, when looking straight ahead be able to catch images out of the tail of his eye. In combat work it is a case of "see the other fellow first." Life often depends on that fact. Hence a sensitive peripheral retina is important.

The test for peripheral vision should be made on the original examination, by a good automatic recording perimeter. The test should be done under standard light conditions, preferably in a dark room with a small light illuminating the test object. It should be done also by a trained examiner, as a novice will usually find contracted fields. Contracted fields are, of course, a cause for rejection as they mean a restriction of the field of vision. A flyer needs unrestricted fields as indicated above. On examinations subsequent to the original, unless there has been a history of disease or injury which might affect the retina, it is not necessary to use the perimeter. The fixation and finger test is sufficient.

In this test the subject faces and looks into the eye of the examiner at a distance of 1 foot. The examiner brings his moving fingers in from the periphery in the six cardinal directions. The subject states when he sees the fingers and how many. He should see them as soon as the examiner, if normal. The test is done on one eye at a time. If there is any doubt about the fields after this test the perimeter should be used.

Cobb (4, 5) has described an ingenious apparatus which he developed at the School of Aviation Medicine. This is called a retinal sensitivity apparatus, and it tests the peripheral vision. Briefly, the apparatus consists of an illuminated white screen 76 by 60 cm. with a small circular aperture in the center backed up by another equally illuminated white screen so that the aperture is not visible at 6 m. A gravity drop apparatus is arranged back of the aperture in such a way that black blinds of various lengths can be made to pass by the aperture, the length of the blind determining the length of the stimulus. The length of the blinds was computed in units of 0.001 second. A black tack is placed 21 cm. to the left of the aperture representing 2 degrees in the visual field. The subject fixes his attention on the black tack. By a telegraph key he releases one of the blinds and indicates whether or not he received the stimulus. His veracity is checked by running in at intervals a blank which does not obstruct the aperture. The average time stimulus necessary for him to perceive the peripheral image is figured. There are three criticisms of the apparatus. First, it is complicated and requires a trained operator; second, there is no assurance that the coöperation of the subject will be obtained and that he will not look at the aperture instead of the tack; and third, the test consumes too much time for a routine test.

Cobb makes the point that in any test of retinal sensitivity that absolute photometric control is essential. This should be borne in mind in using the perimeter.

LATENT REFRACTIVE CONDITIONS

Hyperopia is a condition in which parallel rays of light come to a focus behind the retina. This must be taken care of either by a lens or by constant accommodation.

Latent hyperopia is the chief condition we have to deal with. Hyperopia may be manifest, in which case the visual acuity will be found defective; or it may be latent, in which case the subject by

constant accommodation—even when looking at a distance—maintains his visual acuity at a normal level. This can be detected only by paralyzing the accommodation and then refracting the subject. Its importance will be seen from the statements which follow.

Refraction of the candidate takes time, but on the original examination it is a procedure well worth while. Latent hyperopia can be detected in no other way, and a latent hyperopia of more than one diopter should be considered disqualifying for the following reason. Subjects with 20/20 vision and a latent hyperopia will, under the effects of fatigue and stress in the air suddenly lose their power of accommodation and the latent hyperopia will become manifest, the visual acuity dropping from 20/20 to 20/30, 20/40 or even less. Once determined, there is no necessity of refracting the candidate on subsequent examinations under ordinary circumstances. Astigmatism or myopia of more than one diopter will usually be detected on the visual acuity examination, but if not, it should be considered as disqualifying if found on refraction, because of the strain and fatigue to which they subject the candidate. In both hyperopia and myopia we have a disturbance of the normal relation between convergence and accommodation.

COLOR VISION

Normal color vision is essential in a pilot because he has to distinguish landing lights on an airdrome at night; the navigating lights on other ships; an enemy plane from a friendly one; and finally the distinguishing of color on the ground assists him in recognizing the terrain and in picking out landing places in an emergency. Different colors and different shades of the same color on the ground represent different types of ground and therefore good, fair, poor or impossible landing fields. Colored signals, flares, rockets and panels are used in communicating with a plane from the ground.

Central color vision must always be normal. On the original examination the Jennings's test is best as it forms a permanent record. The Jennings's test consists of 64 samples of colored wool mounted on a perforated tablet—one perforation for each sample of wool. Various shades of the test color are scattered among the confusing colors. A chart is placed under the tablet, and has the positions of the test color noted on it. The candidate is shown a sample of one shade of the test color and told to punch with a stencil each perforation next to any shade of that color. The chart is then removed and the

punches should correspond to the printed notations. The examiner and the candidate each sign it. On subsequent examinations the use of colored skeins of wool is satisfactory. Color vision must be tested at intervals, because glare conjunctivitis not infrequently results in a loss of color vision.

Normal peripheral color vision is essential for night flying. It should be tested by the perimeter at the same time the test for the visual fields is made. Standard colors should be used and the same precautions as to illumination should be taken as in the examination of the visual fields. Any contraction of the fields for red, green, or blue should disqualify for night flying. More will be said about the qualification for night flying under the heading of night vision.

INSPECTION OF THE EYES

The eyes should be carefully inspected for the presence of pathologic conditions and anomalies. The following conditions may be found:

Lids: Ptosis, blepharitis, trichiasis, entropion, ectropion and chalazion

Tear sac: imperfect drainage

Lower punctum: Failure of contact with bulbar conjunctiva

Conjunctiva: Trachoma and old scars

Cornea: Opacities, pannus, and pterygium

Pupils: Unequal size, irregular shape and failure to react to light or accommodation.

Any pathologic condition which may become worse or interfere with the proper functioning of the eyes under the fatigue and exposure of flying should disqualify. Conditions which can be remedied by operation such as pterygium and chalazion should be cleared up before the candidate is accepted. Some of the defects mentioned above such as pannus and ptosis, scars, etc., interfere with vision. Others such as defects of the tear sac and lower punctum, entropion, trichiasis, etc., cause marked lachrymation which is a serious matter while flying.

OPHTHALMOSCOPIC EXAMINATION

The media, iris, disk, blood vessels and retina of each eye should be examined by an ophthalmoscope for congenital and pathological abnormalities, which if found should disqualify. It cannot be emphasized too strongly that the whole eye is involved in flying and defects



FIG. 7. MEASURING ACCOMMODATION

of any part are serious. Diseases or defects of the retina, disc and media interfere with vision or eventually will. Affections of the iris disturb both visual acuity, accommodation, and so on.

ACCOMMODATION

Accommodation is important to the flyer, because he constantly has to change his focus from far to near and back again. He is watching for other planes, looking at the ground and then at his instruments or maps. The reading of the instruments or maps requires from two to four diopters of accommodation.

The rule in the United States Air Service is that accommodation should roughly conform to that normal for age as shown by Duane's table. It should not fall more than two diopters below that normal for age and there should be a minimum of four diopters regardless of age. In trained flyers a minimum of two diopters is accepted. In the case of observers, correcting lenses may be worn. The reason for the rule regarding age is that accommodation and convergence ordinarily go hand in hand. If the accommodation does not conform to that for age, it is perhaps a symptom of disease, of ocular muscle imbalance, of latent refractive conditions, etc.

A satisfactory method of testing accommodation is as follows:

A Prince rule is placed, one end at the anterior focus of one eye, which is 11.5 mm. in front of the cornea. The rule is held horizontally and straight to the front. A slide is on the rule holding a card of test letters according to Thorington's scale. The slide is slowly pushed away from the eye until the letters can be read without blurring. The measurement is then read direct from the rule at the position of the card. The test is repeated for the other eye.

The speed of accommodation is undoubtedly an important factor. Ferree and Rand (9) have described an apparatus for testing this factor. Goodall (10) and later Tefft and Stark (15) studied it as a means of testing aviators. The apparatus is a tachistoscope and it registers in 0.001 second the speed of accommodation from near to far and back again. The test is performed under a standard illumination. The test is unquestionably satisfactory so far as testing the speed of accommodation is concerned but it takes too long and its use requires considerable skill, and the apparatus is too cumbersome for its adoption as a routine test. Tefft and Stark also report other faults in the test so far as aviation is concerned. Those interested are referred to the original articles.

OCULAR MUSCLE BALANCE

While considering ocular muscle imbalance in flying, let us review briefly some of the terms used in order to make the discussion clearer to those who have not recently been working with the eye.

There are six muscles controlling the movements of the eye. These muscles act together in pairs. Those of you who remain on the ground are not so vitally concerned with ocular muscles, for if you desire to look at anything not straight ahead you turn your head rather than your eyes. The aviator, however, must turn not only his head but his eyes to the extreme angle. He must look in all directions constantly. To illustrate how much the aviator twists and turns, it is reported that a number of cases were noted during the war of a considerable hypertrophy of the neck muscles due to constant use. The eye muscles are used even more than the neck muscles. Furthermore, the aviator is subject to fatigue and to stress of a degree not experienced by the individuals who remain on the ground, and this fatigue and stress affect ocular muscle balance.

Under usual conditions the image of an object is received on symmetrical points in the retinae of the two eyes and single vision results. If the images are not received on corresponding points, double vision or diplopia results. This diplopia ensues from a deviation of one eye. There are various kinds of deviation. We may have a paralysis of one or more muscles, either complete or partial. This is easily detected by the associated parallel movements test to be described later. Then we have strabismus or squint. The squint is due to an absence of binocular fixation which ordinarily covers a field 45 degrees upward, inward and outward and 60 degrees downward. The patient cannot overcome the squint. The condition is manifest. The subject either sees double or else sees only with one eye, the other image being suppressed. Squint may be periodic, instead of permanent. In such a case if not apparent, it will be detected in the examination for heterophoria, as a marked muscle imbalance will be found. Periodic squint may be monocular or alternating and is due either to excessive and rapid accommodation or to systemic derangement. Both paralysis and squint are, of course, disqualifying because of the restricted or absent field of binocular fixation.

Lastly, we have a condition known as heterophoria. This represents a tendency on the part of the eyes to deviate. This tendency is not manifest, but latent and is due to a lack of balance between the

opposing groups of ocular muscles. It is corrected by muscular effort caused by the desire for binocular vision. According to May (12) if we cover one eye, that eye deviates but when both eyes are used the deviation is overcome. In heterophoria, then, the eyes are constantly tending to deviate. Ordinarily this tendency is overcome, but in aviation we have conditions that are not ordinary, so that with certain degrees of heterophoria we may get diplopia resulting from the conditions imposed by flying.

There are various types of heterophoria, but those with which we are chiefly concerned are three:

Exophoria—a tendency to deviate outward

Esophoria—a tendency to deviate inward

Hyperphoria—a tendency to deviate upward

Some of the causes of heterophoria are: refractive errors, especially when accompanied by a lack of consonance between accommodation and convergence, and a lack of muscle tone.

We may safely say that ocular muscle balance is one of the most important points to be considered in aviation. Both fatigue and altitude affect the muscles. Wilmer (16) says there is a loss of muscle tone at high altitude resulting in a restricted field of binocular fixation, double vision and a loss of accommodation. As altitude increases there is a progressive falling off in muscle strength according to Cantonnet (3). In normal cases 7.3 per cent show a decrease in the field of fixation while 50 per cent of abnormal cases show a decrease.

Campbell (2) says, "The conjugate action of the two eyes implies, and is the outcome of coördinate action of various groups of muscles, controlled by a brain center. Any disturbance of this neuromuscular machinery causes want of balance or heterophoria, requiring a conscious effort of the will to control. The causes are both general and local."

Heterophoria is a suppressed condition. It causes fatigue and results in inattention or carelessness. In addition there is always the danger of diplopia resulting. Heterophoria is apt to become worse from the fatigue and strain of flying. It is apparent, therefore, that a careful examination should be made of the eye muscles.

Bad landings are frequently due to heterophoria. Wilmer (17) reports that Clements of England found 84.5 per cent of officers turned down for bad landings were successfully treated by training the ocular muscles.

Moulton (13) reports that school training resulted in impairment of muscle balance at 33 cm. Thirty-four out of 133 cases showed a defect of more than 12 diopters of exophoria at 33 cm. following their course at the school.

One of the first things we must know when we find a defect of balance is the strength of the opposing group of muscles. Of all the conditions met, hyperphoria is the most serious, for we have here no opposing group of muscles. Consequently, it is believed that a hyperphoria of more than 0.5 diopter should disqualify except in the case of a trained flyer, when a defect of one diopter may be accepted.

Exophoria is the next serious condition. If, at 20 feet, more than 2 diopters of exophoria are present, with an angle of convergence near or below 40° , it should be considered as disqualifying as we have here convergent muscles that are manifestly weak and which can under right conditions be overcome by the divergent muscles—likewise if diplopia occurs on the tangent curtain it should obviously disqualify. Under any conditions an exophoria of more than 5 diopters should disqualify. Exophoria with the onset of fatigue causes a relaxation of accommodation and a commensurate decrease in convergence, resulting in an increase in exophoria and a development of diplopia.

Exophoria should also be tested for at 33 cm. If more than 12 diopters are present it should disqualify. Such a condition is frequently found in individuals whose general health is below par, or who show signs of "staleness." Flyers who have office jobs or other persons who use their eyes a great deal for near work, will show a high degree of exophoria at 33 cm. Our experience has shown that more than 12 diopters of exophoria at 33 cm. should be considered as the red flag of poor physical condition and should disqualify, at least, temporarily.

Exophoria may be overcome by an improvement in general health and fitness, and by practising convergence exercises. This should be done under the direction of an oculist.

Esophoria is less serious, but there are limits here, also. The rules in the United States Air Service are that esophoria of more than four diopters associated with less than 4 diopters of prism divergence should disqualify, because our external muscles are manifestly weaker than the internal; if associated with diplopia on the tangent curtain, it disqualifies, obviously; if associated with an accommodation near the lower limit, it also disqualifies, because there is a lack of the proper relation between accommodation and



FIG. 8. TESTING FOR HETEROPHORIA

The prism and maddox rod are before the non-sighting eye

convergence which may lead to further trouble (one should in such a case suspect latent hyperopia), and finally if associated with hyperopia near 1 diopter (or more) it should disqualify, for hyperopia is one of the causes of esophoria and a vicious circle may be established. In any case an esophoria of more than 10 diopters disqualifies because here there is too great an imbalance regardless of other factors. In conclusion, it may be said that moderate esophoria due to convergence excess if accompanied by good power of divergence is not serious, but esophoria due to divergent weakness is serious. Fatigue results in bringing to an end the ability to maintain the accommodation necessary to maintain 20/20 vision and the visual acuity falls off.

The best method of performing the tests for heterophoria, is a matter that should be left to ophthalmologists, but it will not be out of place to state the method we have found both rapid and accurate in the United States Air Service.

First, the sighting eye is determined. Dolman (7) found that heterophoria is almost uniformly greater when the sighting eye is used to fix the light. He recommends that the prism and Maddox rod be placed before the non-sighting eye.

The sighting eye is determined by having the candidate look at a spot light 6 meters distant, through a hole in a card held at arms' length, and blocking off each eye alternately. Then a Risley rotary prism and a Maddox multiple rod mounted on a Phorometer trial frame are placed in front of the non-sighting eye. A card 6 by 9 cm. is held in front of the non-sighting eye. The prism is set off the zero mark. All lights are turned off and the candidate is instructed to turn the milled thumbscrew on the prism until the line of light passes directly through the spot light. He is given only glimpses of the line while the card is removed and quickly replaced. The reading is taken from the scale on the prism when he announces that he has succeeded in placing the line through the light. For esophoria and exophoria the prism is placed for measuring lateral deviation or horizontal imbalance and the rod is placed so that the line of light is vertical; for hyperphoria the prism is placed for measuring vertical deviation and the Maddox rod so as to give a horizontal line of light. In testing for horizontal imbalance at 33 cm. a pencil light is held by the examiner 33 cm. from the eyes and this is used for the spot light. The test is then performed the same as the test at 6 meters. The normal condition found at this distance (33 cm.) is 4 diopters of exophoria.

The reasons for using the screen with the Maddox rod are given by Dolman (8).

1. The chief causes of inaccuracy are the tendency to fusion and the phenomena are based on the false projection of the light seen as a line through the rod.
2. A screen placed over the Maddox rod during the test and withdrawn for an instant enables a measurement of lateral imbalance to be made that is accurate and free from any of the general objections made against the (Maddox Rod) test.

Prism divergence is tested by having the candidate fix on a spotlight 6 meters distant. A Risley rotary prism, set for measuring horizontal deviation, is placed before the non-fixing eye and turned slowly inward until the candidate sees double. The reading is then taken from the scale on the prism.

A prism divergence of less than 2 diopters or more than 15 diopters is disqualifying, as indicating in the former case a divergent weakness and in the latter case too great divergent strength. Likewise a prism divergence of more than 9 diopters if associated with an angle of convergence near the disqualifying limit (40 degrees), as this indicates a convergent weakness too marked to overcome the stronger divergent muscles; and likewise a prism divergence of less than 4 diopters if associated with an esophoria of more than 4 diopters; for here we have a divergent weakness. The divergent muscles are not strong enough to overcome the potential strength of the convergent muscles.

The strength of the internal muscles is measured by the angle of convergence. First the interpupillary distance is found. Then the *PcB* is determined. This is the distance of the point of convergence from the base line, the latter being the line determined as connecting the centers of rotation of the two eyes. This is done by placing a Prince rule 11.5 mm. in front of the cornea, the rule extending straight to the front. A white headed pin is then brought in along the edge of the rule toward the bridge of the nose. When one eye wanders off the reading is taken on the rule in millimeters. This reading plus 25 equals the *PcB*. The 25 is added to cover the distance from the end of the rule on the nose to the base line and is composed of 11.5 mm. in front of the cornea and 13.5 mm. back of the cornea. The angle is then figured according to the following formula.

$$\text{Angle of convergence} = \frac{\frac{1}{2} Pd \times 100}{PcB} + 3$$



FIG. 9. MEASURING THE ANGLE OF CONVERGENCE

A table of angles can be figured out so that the formula need not be used at the time of the examination. The whole test will then take but a minute. An angle lower than 40 degrees should be cause for rejection as it indicates a marked convergent weakness. A low angle can be improved by proper muscle exercises under the direction of an oculist.

The associated parallel movements can be tested by the pin and fixation test. The pin and fixation test is performed by having the candidate hold his head steady and follow with his eyes a white headed pin moved by the examiner in the six cardinal directions. The pin is held 33 cm. in front of the subject's eyes. The pin is moved slowly and not beyond the field of binocular fixation. Lagging or overaction of either eye is noted. Any overaction or underaction should be followed up on the tangent curtain. Diplopia on the tangent curtain except at the extreme angles should be disqualifying. The tangent curtain test used is the usual one at 75 cm. distance. The test is performed in a dark room, a red glass being placed in front of the right eye. The candidate is told to follow a pencil light with eyes only, the head remaining fixed. The points of diplopia and the position of the red and white images are marked by pins and then plotted on a blank.

NIGHT VISION

Night vision is important to the flyer, especially in war time as he then has a great deal of night flying to do. There are certain individuals who are night blind—that is they see in good illumination such as daylight, but they cannot see at night. It usually means a form of retinitis. Retinitis pigmentosa is a frequent cause. In this condition we get a lack of sensitiveness in the peripheral retina and a contraction of the field of vision, gradually progressing to complete blindness.

This emphasizes the necessity of examining the peripheral vision as this is very important in night vision. An object is distinguished more readily in a poor illumination, if the image falls to one side of the macula. For this reason a contraction of the fields for form and color in the perimeter examination should disqualify for night flying. It also emphasizes the need for a careful ophthalmoscopic examination as in retinitis pigmentosa we find pigment deposits in the retina and may find beginning atrophy of the disc.

Night blindness may occur without any changes in the retina

that can be detected. It may be a complication of liver disturbances, for example. At the present time, there is no satisfactory short test for night vision. Various tests have been described, however.

Cantonnet (3) describes a test as follows: The subject remains in a dark room ten minutes for adaptation. When the threshold of sensitivity is found where he recognizes two plates having a slight inequality of luminosity, the visual acuity is tested in a very weak light. He uses a photographic enlargement on a ground glass on which a luminous source projects the image of a ring test. Ground glass and a smoked glass so obscure the light that nothing can be distinguished for five minutes. The broken ring test is then made. This consists of a split ring holding a Landolt test, placed 22 mm. from the source of light. The angle between the center of the test and the edge of the light is 15 degrees. The candidate is placed at 5 m. distance and receives in his eyes the divergent rays of light. He should indicate the place of the split in the ring which is mounted on a disc that can be turned by hand. The test is done with both eyes open.

Wilmer (16) states that any test of retinal sensitivity takes too long. He suggests testing contrast sensitivity instead. The Reeves wedge test was used during the war at the Medical Research Laboratory. There is a constant light 75 watts, 110 volts, placed $8\frac{1}{2}$ inches from and at an angle of 45 degrees on a 1-inch gray letter, on a 5-inch light gray background, 20 feet away from the candidate. There are thirteen shades between the letter and the background. One eye is covered and the photometric wedge, consisting of neutral dyed gelatine in wedge shape between two layers of plate glass, the light varying with the thickness of the gelatine,—is passed in front of the open eye until the letter merges with the background. The wedge is in a case and is withdrawn until the contrast disappears. The point on the scale is noted three different times. The reading is translated into per cent transmission.

The Italians use a test consisting of a series of incomplete circles on backgrounds of diminishing shade differences.

EFFECTS OF ALTITUDE ON THE EYE

Altitude affects the various functions of the eye and shows the necessity of fairly normal eyes in the flyer. Wilmer and Berens (18) report that altitude affected the eye in individuals with abnormal eyes more than it did those with normal eyes.

In the case of the field of binocular fixation the field was contracted at high altitude in 50 per cent of abnormal individuals and in only 7 per cent of normal individuals. Sixty-three per cent of abnormal individuals showed a decrease of accommodative power and 47 per cent of normal individuals showed a decrease. Fatigue of accommodation was more rapid at high altitude. Fifty per cent of normal individuals showed a decrease in converging power. In some of the subnormals the recession of the near point was so great as to result in diplopia. Fatigue of convergence at high altitude was also much more rapid. Tests of the ocular muscles at 15,000 and 20,000 feet showed a decrease of the power of abduction, adduction and sursumvergence.

In conclusion then, we may say that normal vision, both central and peripheral, normal color vision, good depth perception, fairly normal refractive condition, no marked defects of ocular muscle balance, good accommodative power and absence of pathological or anatomical defects or anomalies of the eyeballs and appendages are essential in flying.

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CHAPTER III

THE NOSE, THROAT AND EAR IN AVIATION, INCLUDING A CONSIDERATION OF EQUILIBRIUM

The nose, throat and ear are closely allied so far as aviation is concerned and may be considered together. We shall likewise in this chapter discuss equilibrium. While several factors are concerned in equilibrium the internal ear plays a part and it will be convenient to discuss the whole subject at this point.

THE NOSE AND THROAT

The nose must be free from obstruction to normal breathing. The mouth breather cannot satisfactorily expand the lungs. Mendel has demonstrated that the mouth breather inhales with each breath one-fifth less than the normal nasal breather. This has a bearing on oxygen want.

The common causes of nasal obstruction are hypertrophic rhinitis and septal deviations. Septal deviations are easily cured by operation. Ranken (23) states that in recommending submucous resection, it should be kept in mind that symptoms apparently trifling on the ground are aggravated in the air. The obstructed nose also is a cause of frequent attacks of rhinitis and of middle-ear trouble. Nasal polypi and infective sinuses are causes for rejection.

The throat should be free from obstruction and from disease. Hypertrophic or diseased tonsils should be removed. The former are obstructive and the latter are apt to light up in acute infections following exposure and fatigue. Adenoids should also be removed if present.

THE EAR

The ears should be examined from the standpoint of the drums, the middle ear, Eustachian tubes and hearing.

The drums should be healthy and show a normal light cone. There should be no evidence of middle ear disease. Healed perforations of the drum are not disqualifying if the scar is firm and there is no

diminution of hearing. Thin scars are disqualifying as they are liable to rupture. History of mastoid disease is disqualifying, although in the trained pilot, if there is no evidence of present trouble, the drum normal and hearing good, it may be waived.

The Eustachian tubes must be patent. The aviator is constantly changing his altitude, sometimes very rapidly, thus subjecting his ear drums to changing pressure. If the tubes are not patent, the two sides of the drum will be subjected to unequal pressure, rendering the possibility of rupture very great. This is particularly the case on descent. The drums become retracted. The flyer suffers headache, pain, deafness, dizziness, and even unconsciousness and the drums may finally rupture. Scott (25) says "Airmen should not fly with cold in the head, sore throat or when unable to inflate the Eustachian tubes at will."

HEARING

We now come to the question of hearing. Hearing is not particularly important in the aviator. He needs sufficient hearing to detect the functioning of his motor, but he is deaf indeed who cannot hear that. He also ought to be able to hear his mechanic when he says "Contact" or "Switch Off."

For the candidate for the Air Service it is perhaps well to insist on normal hearing, for all aviators become deaf and if the candidate is deaf to start with, he will soon reach the stage where he cannot perform his other military functions. After the flyer is once trained, so long as he has sufficient hearing for his other military duties, he may be allowed to fly. For civilian aviators, it is thought that a third of normal hearing is sufficient.

As to the tests for hearing, there are none that are absolutely satisfactory. The watch tick and the whispered voice are the two most commonly used. If used, the watch should be a loud ticking watch, such as the ordinary stop watch, standardized against five normal persons and the average distance it is heard, noted. Usually 40 inches is the distance used as a standard, but we found at the School of Aviation Medicine that it varied with the type of room used and the way it was held in the hand. For example, when the test was performed in a metal lined room (x-ray room) it was heard much farther than in a room lined with beaver board. The watch should be held in the palm of the hand. The whispered voice test should be performed by whispering with the *residual* air. It should

be heard at 20 feet. A difference in examiners is bound to creep in here, but with the residual air method there is less error.

An audiometer seems more satisfactory. By this apparatus one may test the hearing of each ear separately, for eight different pitches varying from 64 double vibrations per second to 8192 double vibrations per second. The pitches are pure tones and cover the greater part of the range of hearing. The intensity of the pitches may be varied as desired. A description of the apparatus has been made by Michie (18). Pfeffer (21), as a result of work with the apparatus recommends that all applicants for flying training be examined by the audiometer, likewise all radio mechanics and operators, and that all those showing greatly reduced hearing for C4, C5 and C6, be rejected, as these are the tones most commonly used.

SUMMARY

To summarize, then, we desire a candidate of good history who has no disease of the nose, throat or ear, lack of obstruction in the nasal and pharyngeal passages, healthy ear drums, patent Eustachian tubes and normal hearing. For the trained pilot, a reduced hearing is unimportant, provided he has 12/40 with the watch tick (that is hears the watch at 12 inches instead of 40), and 8/20 whispered voice, (that is hears the whispered words given with residual air at 8 feet instead of the normal 20 feet).

EQUILIBRIUM

The next subject to be taken up is that of equilibrium. The aviator is constantly changing his position. He is first upright, then on his side, then upside down and is changing from one position to another, often rapidly. The air is not always smooth and he finds the sensations of flying are sometimes similar to the roll of the ship on the ocean. When flying straight ahead, the wings are parallel to the ground; when making a turn, the wings are banked to an angle corresponding to the sharpness of the turn. The flyer may descend from an altitude in what is known as a tight spiral. In this, he descends in a series of spiral turns in a small radius. The turns are similar to those of a corkscrew. This is quite apt to cause vertigo. In acrobatic flying the aviator may go through a series of evolutions involving disturbances of equilibrium. For example in the loop, he descends slightly to acquire speed, climbs swiftly, finally becoming

upside down, continues flying upside down, the nose of his plane gradually descending until he completes the loop, and without changing the direction of the plane he comes out in the upright position, headed as shown in the appended photograph. In this manoeuvre the plane makes a complete turn of 360 degrees around a transverse axis.

In an Immelman, he goes through the same manoeuvre as in making the loop but after passing the peak of the loop, while still upside down, he rights his machine and starts off in the direction opposite to that which he would pursue if he completed the loop.

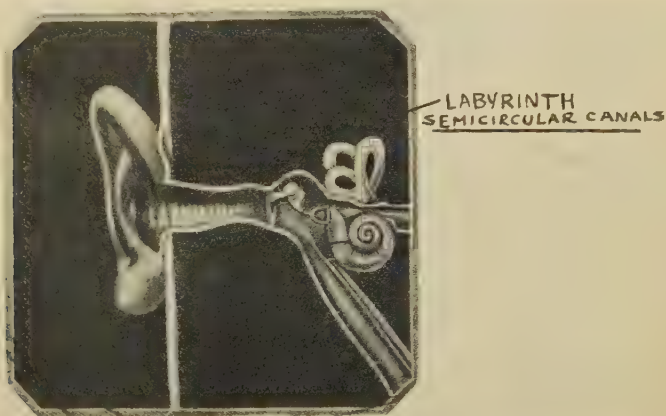


FIG. 10. THE EXTERNAL, MIDDLE AND INTERNAL EAR

In the barrel roll, he turns the machine through an arc of 360 degrees on its longitudinal axis; that is it is rolled in the manner of a barrel from right to left or from left to right without change of direction.

In a tail spin, which is not really an acrobatic manoeuvre, the nose of the plane drops and the plane spins downward, rotating completely around on the nose. The tail of the plane spins through a somewhat longer radius, as shown in the appended photograph.

Acrobatic flying causes considerable stimulation of the factors governing equilibrium. On coming out of the spin, the flyer is likely to be confused and pull his controls in the wrong direction until he becomes thoroughly trained not only in flying, but in interpretation of his sensations. Acrobatic flying is an essential part of the

training of every pilot. Whenever a ship loses speed, it is apt to go into a tail spin. The flyer, therefore, must be familiar with what happens in a tail spin and know how to come out of it. The loop, the Immelman and the barrel roll are necessary in combat work. These manoeuvres are essential when fighting in the air. They also increase the pilot's flying ability and improve his "feel of the ship."

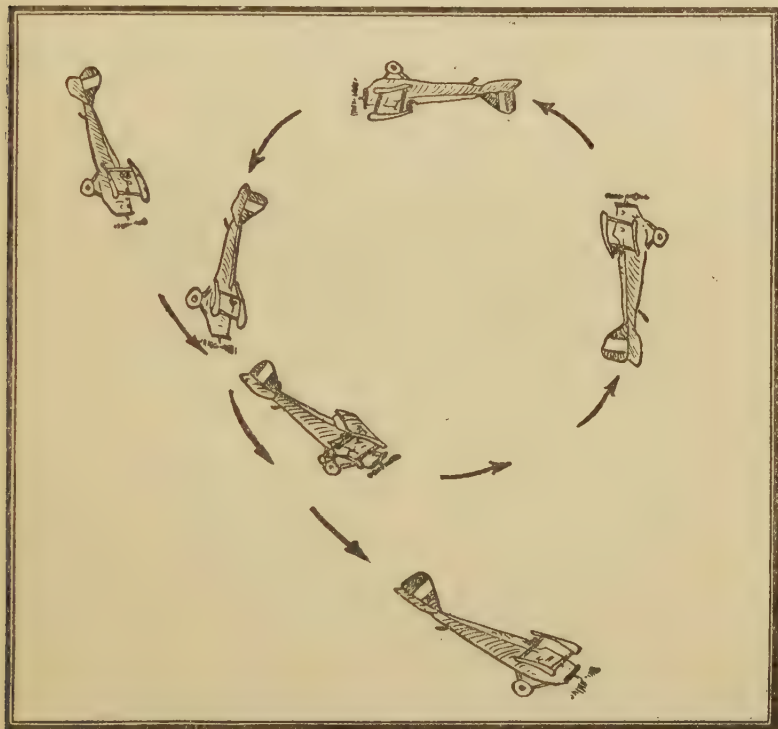


FIG. 11. SCHEMATIC REPRESENTATION OF LOOPING THE LOOP

The pilot is, at one time or another, in every conceivable position with respect to the horizon. His situation, therefore, is quite different from that of the man on the ground who maintains a reclining, an upright standing or sitting position with no rapid changes from one to another. The sense of motion and the sense of the change of direction would seem, therefore, to be of much more importance to the flyer than to the person who remains on the ground. We must stress, then, the factors that have to do with the maintenance of equilibrium and the methods of testing these factors.

There has probably been no subject about which so much dispute has raged. The literature contains about two thousand articles, many of them directly conflicting. When flying was in its infancy the sudden and unusual changes in equilibrium which the flyer had to undergo were considered very important and a large amount of the early literature, particularly in the United States dealt with the subject of equilibrium. Factors that have been considered at one

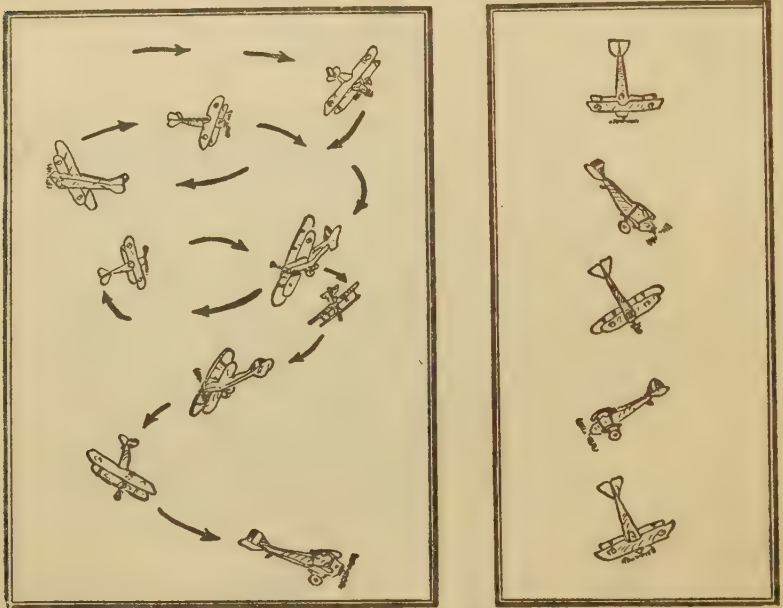


FIG. 12. SCHEMATIC REPRESENTATION OF A TIGHT SPIRAL (LEFT) AND A TAIL SPIN (RIGHT)

time or another as concerned in the maintenance of equilibrium are vision, the vestibular mechanism, deep muscle sense, including sensations from the bones, joints and tendons, and the tactile sense. The brain, chiefly by means of the cerebellum, has been considered as the coördinator of the afferent impulses reaching it from these sources. The relative importance of these factors must now be considered. If one glances over the literature of the American writers on aviation medicine, during the world war, he is at once impressed by the multitude of articles on the equilibratory function of the internal ear. Some of the authors claimed that the ear was the most

important factor in flying, that flying, particularly stunting, was strictly an ear problem etc. The part of the examination which was most stressed was that concerning equilibrium. The tests of Barany (2, 3, 4) were considered all important and were the oftenest repeated.

The subject of otology occupied the center of the stage. That the whole matter was overstressed and that otology is of secondary importance in aviation medicine there is no doubt. Vision, certainly so far as aviation is concerned, is the most important factor in the maintenance of equilibrium. When a man is flying in the dark or in the clouds, he finds great difficulty in maintaining his equilibrium. It is not an uncommon experience for a man flying in the clouds to come through them and find that he is flying with one wing down. At the Medical Research Laboratory of the Air Service (1) in 1918, experiments were made on normal subjects, deaf mutes and tabetics. The experiments were made in high bank elevators and in airplanes, attempts being made to determine the relative ability of the various groups to detect changes in speed and direction.

It was claimed that persons with normal labyrinths could sense changes more accurately than abnormal individuals. However, a close study of the charts seems to indicate that many perfectly normal individuals, when blindfolded were unable to sense accurately the direction of even the more rapid and violent movements in stunting. O'Reilly (19) in Canada found that blindfolded pilots were helpless. The experiments on deaf-mutes showed that while they were unable apparently to recognize to the same degree as normal individuals similar evolutions, they improve with practice as do normal individuals, so it is obvious that other special senses, beside the vestibular contribute to considerable extent in recognition of position and movement.

There were experiments made in fast moving elevators but the results showed chiefly that quick up and down movements are detected chiefly by the semicircular canals, but slower movements were not detected with any degree of accuracy.

The next point to be considered is which factor is second in importance in the maintenance of equilibrium. We may practically eliminate tactile sense from consideration in the aviator. Certainly in winter flying with a heavy flying suit, moccasins, helmet, goggles, and gloves his tactile sense is practically eliminated. The play of the wind currents against his cheek may give him some information but if he is flying inside a cabin or with a face mask, even this is lost.

That leaves us the vestibular mechanism and the deep muscle sense. The latter is difficult to test, but the pilot lays great stress on the pressure against his seat, the visceral sensations and on other gravity effects. Furthermore there is no doubt of the tonic influence of the vestibular mechanism on the muscles. We must, therefore, state that the vestibular mechanism is certainly important in the maintenance of equilibrium, though the whole equilibratory mechanism should be considered integratively. O'Reilly (19) says,

It would seem that the semi-automatic maintenance of aerial equilibrium depends not on the information derived from any one set of peripheral sense organs, but on the correct interpretation of afferent stimuli arriving at the cerebral centers from widely different sources, their correlation and proper utilization in conjunction with the sense of judgment resulting from the pilot's experience.

Before discussing the importance of the labyrinth in aviation it would be well to consider a few points on the anatomy and physiology. The labyrinth consists of the cochlea, which is the essential organ of hearing and has nothing to do with equilibrium, and the vestibular apparatus, consisting of the saccule, the utricle and three semicircular canals. The membranous labyrinth contains endolymph and lies within the bony labyrinth, being partly surrounded by a supporting fluid, the perilymph which separates it from the bony labyrinth. The membranous labyrinth is attached to the bony labyrinth wherever the filaments of the auditory nerve perforate the bone to reach the membranous labyrinth. The membranous vestibule consists of the saccule and the utricle. The saccule communicates directly with the cochlea and indirectly with the utricle. The utricle communicates by five openings with the three semicircular canals. The two vertical canals have a common opening on the posterior wall, while the other openings are independent. The canals, both membranous and bony, are each expanded at one end into an ampulla. There are special sense organs in the labyrinth. These are the maculae acousticae and cristae. The maculae acousticae are located in the saccule and utricle and the cristae are located, one in the ampulla of each semicircular canal. These sense organs consist of hair bearing cells receiving filaments of the eighth nerve. Overlying these hair cells are the otolith membrane in the maculae acousticae and the cupulae in the cristae. For a more detailed description of the anatomy the reader is referred to any standard textbook on anatomy.

We now come to the physiology of the vestibular mechanism and this is something that is not yet wholly clear. The school that held sway in this country during the war was the so-called Vienna School. Their theories were based largely on the work of Barany. The chief exponents of this school here were Jones (11) and his associates. This theory is based on a supposed flow of endolymph in the semicircular canals and he ascribed distinct functions to the vestibules and to the semicircular canals. He considered that a static sense was located in the saccule and utricle and that a kinetic sense was located in both semicircular canals and the vestibule. He considered that information was given as to the position of the body at rest by the otoliths pressing on the maculae of the saccule and utricle. Lineal movements were supposed to be detected by the utricle or saccule, or by both, and rotary movements by the semicircular canals. Rotary movement sets up a movement of the endolymph which stimulates the hair cells in the ampullae of the semicircular canals.

Jones explained the phenomenon of rotation as follows: It is well known that rotation in a given direction causes a nystagmus in the opposite direction. Nystagmus consists of two parts, the first part is the slow component which moves the eye in the direction of rotation and was considered by Jones as purely reflex. The second part of nystagmus is the quick return movement and was considered by Jones as being cerebral in action, in other words, the brain, becoming conscious of the fact that the eyes were being jerked to the right, compensates by jerking them back. The endolymph continues to flow after the rotation has ceased, therefore the stimulus is kept up, the eyes are again jerked in the direction of rotation, again compensated for and this continues until the endolymph comes to rest. Douching the ear drum with hot or cold water also causes a nystagmus and Jones also considered this as due to the same cause. The changes in temperature caused a change in the density of the fluid and a current was set up. He based his statement that nystagmus was part reflex and part cerebral on the fact that he claimed if a subject is under the influence of an anaesthetic and the ear doused, there will be a conjugate deviation of the eyes and no nystagmus.

Jones used the Barany tests which provide that the subject should be rotated in the revolving chair exactly ten times in twenty seconds. His head is drawn forward so that the tragus of the ear is on a level with the external canthus of the eye, as this position places the horizontal canals in a horizontal position. The subject's eyes are

closed while he is being rotated. When rotation stops he is told to open his eyes and nystagmus results, to the left if he has been turned to the right and to the right if he has been turned to the left. The after-nystagmus persists on an average of twenty-six seconds. Jones claimed that there was no reduction in after-nystagmus as a result of practice.

Jones explains past-pointing as follows: The subject is turned exactly ten times in ten seconds under exactly the same conditions as pertain in the nystagmus test. Before turning, his eyes are closed. He is directed to touch the examiner's finger which is directly in front of him and then to raise his arm straight above his shoulder and quickly bring it back, again touching the finger. The normal subject should be able to do this. After turning the subject is again told to touch the finger. If he has been turned to the right he will bring his finger back not on the examiner's finger but to the right (subject's) of it. Jones explains this by saying that the flow of endolymph which has been set up to the right persists after the turning has stopped. He has a subjective sensation of turning away from the finger of the examiner. In other words, having been turned to the right, when the turning stops, the endolymph continues to flow and the subject has the sensation of turning to the left, consequently he reaches for the finger, not where it is, but where he thinks it ought to be. Inasmuch as his sensation of turning to the left is purely subjective he past-points to the right of the finger. He will do this with both right and left arms, as long as this false sensation persists. This false sensation of turning to the left is vertigo. Past pointing is in the direction of turning and vertigo is in the opposite direction. The subject is then turned to the left ten times in ten seconds and he will past point to the left.

Jones considers that past pointing is a cerebral act of orientation. He considers that it tests not only the labyrinth but a great part of the central nervous system. Lewis (14) believes the same thing. He stated that past pointing gave definite information concerning the integrity of parts of the medulla, pons, cerebrum and particularly the cerebellum. For that reason Jones and Lewis (12) both felt that past pointing was an essential test for the aviator in addition to the nystagmus test.

The falling reaction is explained as follows: In this test the subject is placed in the chair with his head at an angle of 120° . This brings his vertical canals into the horizontal plane. He is then rotated to



FIG. 13. TESTING THE VESTIBULAR MECHANISM
The rotation test of Barany

the right five times in ten seconds. When rotation stops he is told to sit up and falls to the right. On sitting up the plane of his vertical canals has shifted 90 degrees so that instead of having a sensation of rotating to the left, as he would if his head remained down, he has the sensation of falling to the left and he compensates for this by falling to the right. The test is repeated by turning the subject to the left five times in ten seconds, following which he will fall to the left. These are the tests, nystagmus, past pointing and falling, which, of those originally devised by Barany, were adopted by Jones for the examination of Air Service candidates in the United States. The other tests of Barany were considered necessary only to diagnose suspected pathological conditions. As these three are the only tests in use, our discussion will be limited to them. The Jones theory has been subjected to bitter attack and the large part of it has been shown to be erroneous.

The work of several other observers must be taken into consideration. Ewald (8) definitely proved the influence of the labyrinth on muscle tonus. Attention to the possible connection between these two has already been indicated. Maxwell (17) showed that after section of the two vestibular nerves or destruction of both labyrinths in the dogfish, that no forced positions or movements resulted. The animal is able to swim apparently quite normally. However, if the fish is placed in the water belly up, it may not right itself for some time. If suddenly or greatly excited, disturbances of equilibrium may result. No eye reactions are noted. He found that in mammals destruction of both labyrinths did not result in as marked disturbances of equilibrium as destruction of one. While severe reactions followed, the symptoms gradually disappeared until there was little to distinguish the operated from the normal animal. There was, however, some loss of skill in the use of voluntary muscles and in the case of a dog, he became disoriented when blind-folded. In experiments on pigeons, he showed that compensatory movements of the eyes could be called forth by movements of images on the retina and also that retinal stimulation could modify the effects of excitation arising in the labyrinth. He came to the following conclusions.

(1) Each labyrinth functions only for rotational movements in one direction; the compensatory movements to the left during rotation to the right are excited from the right labyrinth only, and the after effects (compensation to the right), are caused by the left labyrinth. (2) Compensatory movements during rotation are excited both through the eye and the ear. (3) The labyrinth gives rise to an after-effect when the rotation stops, but the retina does not.

He obtained very definite reactions from stimulation of the ampullae of the horizontal canals of the dogfish and finds that the stimulation of the ampulla results in the same movements as are produced by rotation of the animal in the plane of the canal. As a result of stimulating and extirpating the ampulla, he comes to the following conclusion.

(1) All the compensatory movements can be produced through the excitation of the ampullae. (2) All the compensatory movements except those in response to rotation in the horizontal plane can, in the absence of the ampullae, be brought about through the action of some other part of the labyrinth.

In experiments on the otoliths he concludes that it is a displacement of the otoliths and not a pressure due to the weight of the otoliths that causes the actual stimulation, and the direction of the stimulation determines the direction of the compensatory movements. He concludes that the ampullae alone without the otoliths are sufficient for all the dynamic function of the equilibration of the ear and that the otoliths alone suffice for all the dynamic functioning except response to horizontal rotation. In investigating this dynamic function, he proves rather conclusively that no current is produced in the semicircular canals by rotation. He sectioned the right horizontal canal and raised it to the vertical position. In this position it could not give rise to a current and yet he got the same reaction as he did from a canal in the normal position. In rotating the animal in the plane of the new position of the canal, no deviation of the eyes resulted as there would have if the rotation had caused a current in the canal which excited the ampulla. He believes that the symptoms are due to a change in tension. He believes that symptoms resulting from the caloric douche can be explained by the difference in specific gravity which would be produced in the vestibules, causing changes in tension, perfectly consistent in their effects, with the changes in tension he believes produced by inertia during rotation. He found that excitation in the ampullae and in the otolith organ shows that both depend on the same principle. He believes there is nothing to justify the assumption of localized functional differences in the different parts of a single crista or macula. He also showed that nystagmus could be produced in a decerebrate animal.

That the cerebellum is not necessarily involved with the effects of labyrinthine stimulation has been shown by DeKleijn and Magnus (13) who demonstrated that the reflexes resulting from stimulation

of the labyrinth including rotation nystagmus occurred when the cerebellum had been removed.

Griffith (10) in an historical survey of vestibular equilibrium discusses the internal ear as a factor of equilibrium and states that the internal ear is the seat of a receptor which stands in very close relationship with the equilibrium of the body but that it may not be the sole organ of balance. He adds that the principle of inertia may explain the mode of excitation of the vestibular receptor; that there is nothing to show that inertia of the soft parts of the trunk or its appendages does not play a more or less important part in the perception of changes of position. Changes of pressure occur in the canal system and this pressure affects the organs in the ampullae and that while the canals may play a relatively large part in the perception of rotation we cannot assume that equilibrium is maintained solely by this apparatus.

With reference to the matter of muscular tonicity, the same author states that, "The ear contains a mechanism which is adapted to maintain the position of the body in space, to make it cognizant of translational and rotational movements, to keep it in a constant state of tonicity, and, finally, to enable it to compensate, by appropriate movements, changes that may occur in its position." He adds that the canals are structurally connected through the cerebellum with all parts of the body musculature and, that, therefore they are in a position to play a large part in the maintenance of bodily posture as well as to maintain muscular tonus. He attacks the conclusions drawn by Jones and his associates by stating that nystagmus can be modified in supposedly normal subjects and states that the conditions resulting from rotation in the Barany chair are not at all similar to conditions in the air, because the axis of rotation, the rate, the spin effect and the whole emotional and voluntary setting are different. Referring to the claim of Jones that past pointing and falling are cerebral acts, he claims that automatographic records taken during and after rotation prove that past pointing and falling depend upon innervations as involuntary in character as nystagmus. Referring to the claim of Jones and his associates that the different parts of the vestibular mechanism are for different functions, that some can be modified and others not, he states,

We must insist again that the effects of rotation are an integrated group. We have found every member of the whole group to be equally modified by repetition and by other changes in the conditions of arousal. The logical

separation made by the otologists leads them into the impossible position of admitting a modification of vertigo and falling and denying it to nystagmus.

In the final summary he states that the semicircular canals, the utriculus and sacculus seem to be closely connected with the maintenance of equilibrium, that the theory of endolymph movement has little in its favor; that small changes in pressure may occur in such a way as to excite the nerve endings but that conclusive evidence regarding the mode of operation has not been secured; and that the canals must not be considered as the sole means of bodily equilibrium. Finally he states:

In contrast to the clinical description of the vestibular functions, recent investigations have shown that the ocular movements are not simple reflexes, that there is no such mental element as "vertigo" and that the whole group of effects issuing from vestibular excitation must be considered, not as unrelated responses, due in part to cortical and in part to subcortical mechanism, but as a highly integrated and coordinated totality.

Pike (22) states that, "In view of Maxwell's results, there seems good reason for believing that the normal excitation of the ampulla endings is the transmission of pressure from the utricle to the ampullae." Pike found that the cat or dog who has had one of its labyrinths removed will jump over the side of the cage without falling or showing any defects of movement but after a bilateral operation the dog will not jump from even a moderate height to the floor without falling in a heap.

Dodge (6) has investigated thoroughly the question of nystagmus. This is a matter which was a much mooted question during the war. Two groups of observers at the Medical Research Laboratory in 1918 (1), one comprising the otologists headed by Jones and the other the psychologists, headed by Dunlap, came to diametrically opposite conclusions. The otologists claimed that practice never reduced after-nystagmus time in the normal individual. The psychologists claimed the contrary. Dodge has proved conclusively that the psychologists were right. In one experiment, during six days a subject was rotated in the same direction 114 times each day at a uniform speed. The resulting eye movements were recorded photographically. The results showed that the amplitude of after-nystagmus decreased from day to day and also there was a tendency for it to decrease from record to record on each experimental day. The decrease in amplitude is more rapid at first and then becomes more and more slow. During the last three days of the experiment

all records after the first showed that the amplitude of the nystagnus reached zero. When the nystagnus disappears an uncorrected compensatory drift may still remain.

He found that the saccadic (or second) phase of nystagnus disappeared before the compensatory (or first) phase. He believes this to be in accordance with the theory that the two phases originate in different parts of the nervous system and that the fact that the saccadic phase disappears first supports the view that its point of origin is higher. He found evidence that the compensatory phase is a true reflex to rotation. The saccadic phase appeared to be a corrective reaction to the reflex displacement of the eye. The day after the experiment had ceased, he rotated the subject in the opposite direction and found that about one half the training to rotation in one direction had been transferred to rotation in the other. A week later, it was found that there was a slight loss of training which was shortly made up. He found that vertigo and unpleasantness disappeared during the training. He found that habituation to oscillation likewise resulted in a diminished amplitude and eventual disappearance of saccadic movements.

In other experiments on the threshold of rotation Dodge (7) found,

1. Vestibular data from rotations of less than 2 degrees per second are quite unreliable. With double that velocity judgments are often false.

2. Taking our previous study of the results of protracted rotation into consideration the vestibular problems in flying would seem to be:

- (a) Under what conditions in the air are vestibular data sufficiently accurate to be useful?

- (b) How may vestibular illusions of rotation be corrected or compensated?

- (c) How may we develop, coördinate, and systematize data from the various parts of the receptor-field into the most effective control of flying under varying circumstances? These circumstances should include the temporary loss of visual data at night or in fog, as well as the illusions of vestibular and of centrifugal origin.

Maxwell (16) also proved that after-nystagnus following rotation decreases with practice. He also stated that the amount or duration of after-nystagnus following rotation is no reliable indication of the functional activity of the equilibrial apparatus. Other workers have corroborated the reduction in nystagnus with habituation to rotation or douching.

The International Medical requirements formerly stated that the vestibular mechanism must be intact and neither unduly hypersensitive nor hyposensitive. Now the words "nor hyposensitive," have been eliminated.

Ranken (24) believes the value of the chair tests is problematical. He found that (1) experienced pilots have a tendency to diminished labyrinthine reactions, (2) disturbances, past or present, of some other system of the body may affect the labyrinthine reactions, (3) that wherever deafness is present no medical examination of a candidate or pilot is complete without careful investigation of the functions and reactions of the vestibular mechanism (4) in the absence of disease and past or present signs or symptoms pointing to an oral infection, routine examination by the Barany tests is superfluous, provided a thorough medical examination is made.

Burt (5) concluded that an aviator was slower in perceiving the pitch of his machine than he was the roll, in other words, the perception of the lateral tilt is more easily noted than a longitudinal, and a forward tilt is more readily perceived than a backward.

Fridenberg (9) claimed that too much stress was laid on the labyrinthine reactions from the aviation standpoint. Labyrinthine disease is extremely uncommon and would be seldom found in candidates for aviation. He called attention to the fact that vertigo may arise from many other causes such as neurasthenia, anemia, ocular anomalies, etc.

Parsons and Segar (20) examined 100 naval aviators and compared their Barany reactions with their flying ability. They found an absence of correlation between equilibrium as evidenced by Barany reactions and actual flying ability. In another article they reported examination of six whirling dancers and acrobats. In five there was no falling reaction and abnormal past pointing was present. In three, nystagmus was well below normal. Lewis and Pike (15) claim that acrobats and Russian dancers show normal reactions.

If one does the past pointing test on an experienced pilot, he must expect to find little or no past pointing in a large number of individuals. Pilots who do a large amount of acrobatic flying will not past point. If there is any past pointing it will be noticed at the top of the swing rather than at the bottom. In the falling reaction, the test pilot will frequently not fall at all or will fall in the wrong direction. If the caloric douche test be performed less change in the reactions will be elicited. The absence of past pointing or falling, or of falling in the wrong direction are merely compensations by the pilot caused by habituation. That such a pilot is unfit to fly merely because he does not meet the standard of the Barany turning tests is ridiculous.

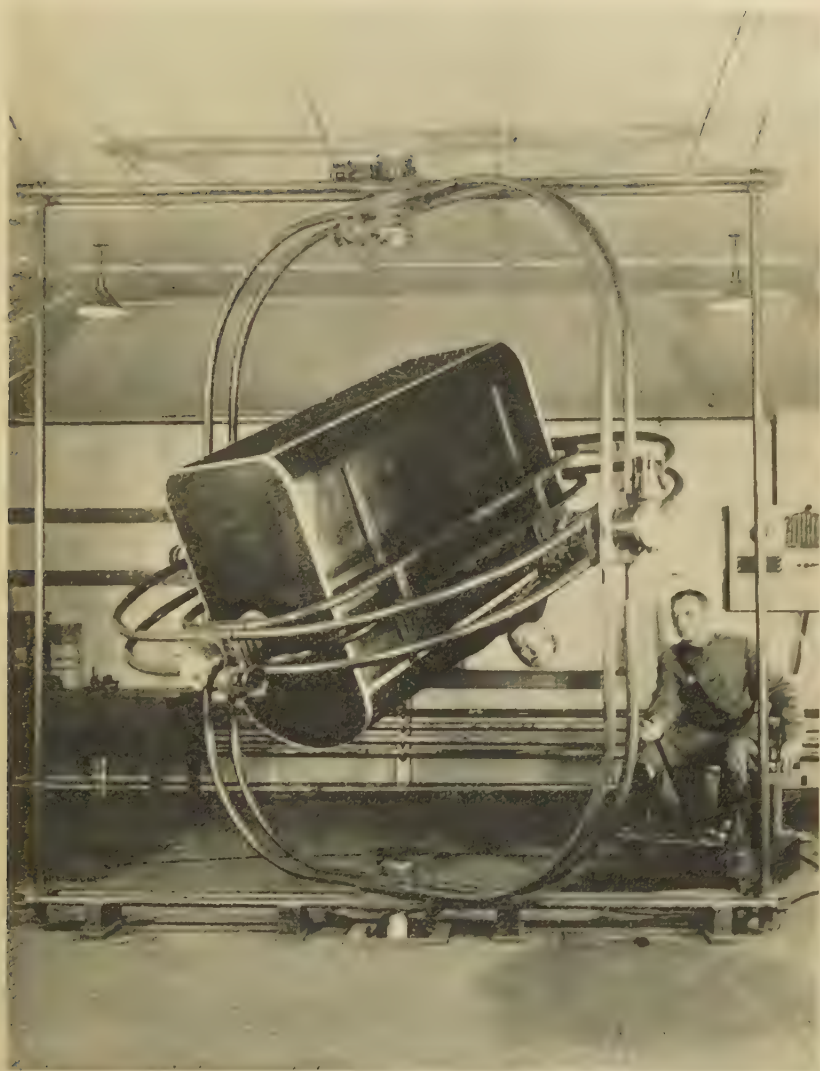


FIG. 14. THE RUGGLES ORIENTATOR

Nystagmus rate is often reduced in the pilot, but not to the extent we might expect from Dodge's work. The reason for this is that the repetition of the rotating movements is at less frequent intervals, the movements are made through a wider arc and at a slower speed. If the Barany tests are not satisfactory the candidate should not be rejected until the caloric douche test has been performed.

The hypersensitive individual is very easily confused by rapid changes in position in respect to his environment. Consequently when he goes into the air and does acrobatic work he is apt to become very confused following a spin, tight spiral or other stunts and be unable to right his machine in time to escape accident. The experienced flyer not only becomes used to his sensations but his sensations become less marked and he is not easily confused. As already stated, the test pilot becomes immunized to rapid changes in motion; dizziness and vertigo disappear and he is able to interpret his sensations so that he shows little reaction to rotation or other rapid changes in position. The whirling dancer, for instance, is able to stop suddenly without falling, whereas the novice will fall.

With this in mind, an apparatus was developed during the war known as the Ruggles orientator. Briefly the apparatus consists of a cockpit of an airplane suspended in three concentric rings. It is operated by motors and is controlled by a stick and rudder in the cockpit or by a stick and rudder in the instructor's chair on the ground. By a combination of movements of the stick and rudder, the orientator can be put through any evolution that a plane can be put through except straight forward, or up and down motion. In other words, it can be looped, rolled, spun, put through a tight spiral, an Immelmann, etc. These movements are similar to those made by a plane except that they are made at a greater angular velocity. The effects, therefore, will be more severe than those experienced in a plane.

The original idea was to train a man in the orientator in conjunction with his flying training, accustoming him to rapid changes in his position in space with respect to the horizon, so that when he actually went into the air he would be less confused and less apt to have an accident during his early training. The orientator came into disrepute because some claims were made that it would teach a man to fly. This, of course, it will never do. Recently at the primary flying school of the United States Air Service, the orientator has again been used in connection with the flying instruction, purely

for the purpose of shortening the period of training, and an effort has been made to pick out men who are slow reactors and will not make good pilots. More will be said about this in a later chapter.

Our present regulations describe the test in use. The candidate on original examination is tested for nystagmus, past pointing and falling. In the nystagmus test the candidate is rotated ten times to the right in twenty seconds, his head at an angle of 30 degrees forward and his eyes closed. As turning stops he opens his eyes and nystagmus is measured by a stopwatch. A nystagmus rate of anywhere from ten to thirty-four seconds is allowable. The candidate is then rotated to the left ten times in twenty seconds under the same conditions. Nystagmus rate should not vary markedly in the two directions. This has lowered the minimum limit formerly established by six seconds. So long as the individual has no labyrinthine disease a hyposensitiveness is no contra-indication to flying. The upper limit has likewise been reduced from thirty-six to thirty-four seconds. The hypersensitive individual, experience has shown, is a much poorer risk in flying than is the hyposensitive individual. The high strung individual and the stale pilot all show a hypersensitiveness. Such a person is easily made sick and becomes readily confused in acrobatic flying.

The past pointing test is performed exactly as was prescribed in the original examination, likewise the falling test. On subsequent examinations the nystagmus and falling tests alone are carried out, the past pointing test being omitted.

So called border line cases or cases giving unsatisfactory results in the chair can be tested by the caloric test (26), each ear separately. Water at 68°F. is allowed to run into the external auditory canal from a height of about 3 feet through a stop nozzle. With the head tilted 30 degrees forward, until the eyes are seen to jerk and the individual becomes dizzy. This should be accurately measured by a stop watch. The type of nystagmus is then noted. With head in upright position, it would be rotary and the direction of the jerk should be to the side opposite the ear douched. The length of the douching shown by the stop watch in the normal is forty seconds. The eyes are then closed and the past pointing taken. The head is then immediately inclined backward 60 degrees from the perpendicular; there should appear a horizontal nystagmus to the side opposite the ear douched. The eyes are then closed and the past pointing is taken with the head in this position. The left ear is

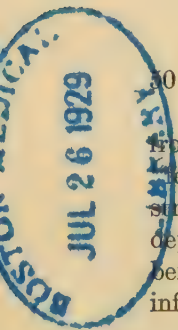
then douched and the same procedure is carried out. If instead of forty seconds of douching there was required not more than 90 seconds the examinee is not rejected. Care should be taken that the cold water reaches the drumhead, as wax or other obstruction in the external canal would interfere with the responses in a perfectly normal individual.

One might ask why the caloric douche test is not performed in the first place. The reason is, that the test is extremely disagreeable and usually makes the candidate sick, so that if it is not necessary to use it, it is better not to do so.

SUMMARY

We may summarize, then, by saying equilibrium is a function maintained by the whole proprioceptive mechanism. Vision plays an important part for the aviator. Likewise the vestibular mechanism and the indefinite "muscle sense" or "feel of the seat." The vestibular mechanism consists of the vestibule, and the semicircular canals. The vestibule is divided into the saccule and utricle. All parts have an integrative action and the sensations caused by changes in position and by rotation are received on the end organs and transmitted by filaments of the vestibular nerve. These end organs receive their sensation from changes in tension brought about in the endolymph. There is no positive evidence to support the endolymph flow theory, and much against it. The clinical interpretation of the Barany reactions have probably received undue emphasis in aviation and misinterpretations have resulted. We know from actual experience in aviation as well as from the results of the experimental work already cited, that all symptoms derived from stimulation of the labyrinth are subject to decrease in intensity and duration. It is very questionable how much reliability can be placed on the Barany tests in the case of an experienced aviator. The whole subject has been unduly stressed in proportion to its relative value in aviation.

The Barany tests lay too much stress on rotation in the horizontal plane. Perception of changes of motion as found in tipping or tilting are of more value to the aviator. Nystagmus is very variable and not of great significance unless of long duration (over thirty-four seconds) or markedly different in the two directions. There can be no doubt that the reduction of after-nystagmus is advantageous. The past pointing test is of little value in the experienced pilot. What is needed is a test involving perception of changes of motion



from one plane to another, and if possible, a test to determine that "feel of the seat" or "visceral feel" that the aviator lays so much stress on. At present, however, we have no such tests and we must depend on what information we can obtain from the Barany tests, being careful to interpret them properly in the light of our added information about the equilibratory function.

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CHAPTER IV

NEUROPSYCHIC FACTORS

Stability of the nervous system is exceedingly important in the flyer. It will be appreciated when we consider that about 80 per cent of the groundings, temporary or permanent, in the past, have been for nervous instability. There are many flyers in the United States Air Service today who are having frequent difficulties, that never would have been selected under our present system. During the early days, so much stress was laid on the ear that other points were lost sight of. The examination of the nervous system was perfunctory and amounted to little. Nowadays, it is considered as one of the two most important factors in the selection of the flyer and the most important factor in the care of the flyer once selected.

All writers on the subject today agree that nervous stability is highly important. This part of the examination is being stressed more and more in the examinations of all nations.

The flyer is subjected to unusual and cumulative stresses, capable of disturbing the stability of any nervous organization. His selection from this standpoint is a strictly individual and highly specialized problem. Not only must there be a thorough neurological study but also close scrutiny of the entire mental life with a view to determining trends, resistances, and potentialities, and in view of these latter, the probable reactions to the experiences inseparable from his daily work. To make this examination, a thorough grounding in neuro-psychiatry is necessary. The reason for this will be seen as the examination is developed. One is not apt to meet psychoses in the aviation candidate any oftener than in candidates for other branches of the service. Nor is one apt to meet the psychoneuroses more often. However, the stress of flying brings out tendencies and emphasizes nervous deficiencies. These conditions are serious in a flyer and while they might not disqualify for ground work, they emphatically do disqualify for air work. The earliest work on this subject in this country was done by Paton, MacLake and Hamilton (6). This was followed up by MacLake (5) and the

present examination and method of making it was more fully developed by Longacre (3).

The discussion of this examination will be devoted largely to Longacre's excellent paper on personality study which is a revision and fuller development of those by MacLake (5), and Paton, MacLake and Hamilton (6) and to Longacre's outline (4) of the neuropsychiatric examination which is used at the School of Aviation Medicine. There is nothing written that covers the subject so fully and the greater part of what follows is taken from these authors.

First we will consider the purpose of making the personality study. Longacre states that it is to study the condition of the candidate's nervous system. An effort is made to determine whether there are deviations from the normal and if so whether these deviations are sufficient to disqualify him from flying; to study the candidate's temperament, intelligence and volition and again to determine deviations from the normal for the same reason; to study the manner of the candidate's reaction to his environment and to unearth latent tendencies which, under the stress of flying, might become accentuated in such a manner as to render him inefficient; and to determine the personality trends, resistances and potentialities.

The procedure in making personality study is as follows: The examination should be made in a quiet room, the candidate should be alone with the examiner and the environment and the attitude of the examiner should be such that complete coöperation can be secured. Longacre emphasizes the fact that the investigation must be conducted informally and that questions should be asked in the accusative form, such as for example, "How much do you drink?" and not "Do you drink?"

FAMILY HISTORY

The first point taken up is the family history and the points to be investigated are the presence of insanity and other nervous diseases in the forbears. The existence of either one favors at least an inheritance of instability. A history of psychoses is more important than a history of the psychoneuroses but in either case there is a probability of transmitted instability. The presence of occasional insanity or nervous diseases in the family history is not necessarily disqualifying but it indicates probable latent instability, and should be considered in connection with the other findings.

PAST HISTORY

The second point is personal history. This history should be taken from birth on. On the infantile period, inquiry should be made as to the history of birth trauma and developmental history, particularly as to the age he learned to walk, talk and cut his teeth. Delay beyond the average age in any of these indicates mental retardation as a rule. Numerous and severe diseases of childhood, especially nervous diseases and defects are among the factors that lead to inefficiency in aviation. This applies not only to childhood, but to severe infections and to mental and nervous breakdown in adult life, whereas a good physical history is an indication of a favorable type. Particular attention should be paid to the development of epileptic equivalents and to the formation of nervous habits, such as nail biting, stammering, somnambulism, pavor nocturnus and enuresis.

Was his temperament normal as compared with other children? Was he an only child? His environmental factors should be brought out, particularly with the idea of determining his personality trend. We wish to know in this connection his family, social and educational environments; whether they were such as made for happiness and contentment. Did he develop along normal lines or was he discouraged and depressed? By whom was he brought up, that is, by one or both parents or by someone else?

His play life is next considered. We wish to know whether or not he got along with other children and with what children he played, that is whether they were of the same age and sex. What sports did he indulge in and in what one did he excel? Rippon and Manuel (7) call particular attention to sport and believe that a history of indulgence in sports and a continuation of such indulgence beyond school age is desirable. Does he have any hobbies? and if so what are they? Unusual ability in athletics is considered a favorable factor, particularly in the individual type of athletics such as tennis, golf and track. The type of athletics which stresses team work to the exclusion of the individual initiative is not so favorable in its development of the individual for air work. In this connection, evidence of manual dexterity is also a favorable factor. The ability to play the violin, piano or play billiards is indicative of manual dexterity.

Under sex life we wish to know his attitude toward the opposite sex, how many love affairs he has had, how they have affected him

and what his reaction to them was. If married what is his attitude in the relationship? His specific sex demands are inquired into particularly as to amount and presence of abnormal reactions or perversions. Finally, we want to know what his general attitude toward sex has been. Does he consider it natural or something to be ashamed of? Normal sexual tendencies are considered a favorable factor.

We now come to his education. We wish to know how he got along in school and college. How did he stand in classes and did he have any failures? Did he ever become ill at the time of his examinations or when in a difficult situation? What determined his choice of career? What is his choice in literature and how fully does he seem to have improved his opportunities? A history of high school and college education with good scholarship throughout is preferable, whereas inadequate education with poor scholarship is an unfavorable factor. Failure in school or college or an uncompleted course should be considered unfavorable unless there is adequate explanation.

During childhood and youth what was his disciplinary record? How did he react to discipline and to those who disciplined him?

His trends of thought are next investigated. How does he look upon his past? What is his attitude on topics of the day, how does he estimate himself and what does he believe others think about him? Inquire into his present occupation and his success at it. Lack of success in occupation or frequent changes in occupation should require adequate explanation.

Find out his favorite amusements and the attitude of his family toward his flying. What effect does this attitude have upon him? The liking for normal amusements without a tendency to excesses or dissipations is considered favorable, but on the other hand a lack of interest in amusements or evidence of excesses are considered unfavorable. As to occupation, a sedentary occupation with poor or moderate success is not considered good ground work for future flying. To have the coöperation of the family in everything pertaining to flying is desirable, while opposition to flying, particularly if the candidate be married and the opposition is on the part of his wife is very unfavorable.

Inquire as to the amount of tobacco and alcohol used. An excessive use of either one indicates an instability. The drug habit will not be found frequently as such. However, make inquiry as to

whether or not there is habitual use of patent or other medicines for ailments, particularly those mild in character. Moderation in the use of tobacco and alcohol and normal sex activities are desirable.

We then wish to know why he selected the Air Service, and, if he is already in the Air Service, we wish to know his aviation history. Particular investigation is made of accidents, crashes and his reaction to and the causes of them; whether or not he has ever been grounded and if so the cause and his reaction to it. What degree of interest does he have in flying? Desirable factors are flying experience or thorough flying training with good standing in his classes, extended flying experience with no history of accidents or crashes. On the other hand a poor record in preliminary training, poor judgment in flying, apprehension, frequent accidents or crashes and poor reaction to the same should be considered as disqualifying. If he has been in combat special search should be made to determine unfavorable reactions to it, which, if found, should be considered disqualifying.

The particular point that should be stressed during this examination is to bring out deviations from the normal along the lines laid down in the following examination. This mental examination is accompanied by a neurological examination. The outlines of both as taken from the physical examination in the United States Air Service follow.

PSYCHIC EXAMINATION

History concerning syphilis, encephalitis lethargica, epilepsy and psychic traumata such as highly emotional experiences. In relation to epilepsy make searching investigation of entire life record not only for history of injuries either major or minor, but for those equivalents indisputably establishing the epileptic background such as somnambulism, enuresis, dizziness, speech disturbances, fainting and migraine. Given sufficient preponderance of such equivalents with or without seizures, the candidate will be disqualified. Inquire as to history of headache, showing frequency, associated symptoms, periodicity, etc.

Financial, family or social difficulties. These will be brought out in the consideration of the following.

(1) Phobias (or morbid fears and dreads) disqualify, inasmuch as they indicate a deeply seated psychoneurotic taint and inability to compensate and sublimate as does the normal individual.

(2) Worries. Deeply seated worries approximating anxiety type are cause for disqualification on original examination, and for grounding the flyer, either temporarily or permanently. An anxiety neurosis disqualifies.

(3) Conflicts. Inadequately handled are cause for rejection on original examination, and for grounding the flyer, either temporarily or permanently.

(4) Complexes (a complex is a constellation of ideas buried in the uncon-

scious and striving for expression). The personality study will determine the types of complexes and their effects; complexes inadequately compensated show an inherent instability and will be deemed disqualifying.

(5) Irritability and apathy. These are disqualifying if found on original examination, and for grounding the flyer, either temporarily or permanently; these conditions require careful study with view to determining whether there is neuro-circulatory asthenia, alcoholism, or precox trend.

(6) Elation and depression. Tendency to be up or down in mood disqualifies on original examination; it is cause for grounding the flyer, either temporarily or permanently, and calls for examination to determine the degree of manic-depressive coloring.

(7) Sensory disturbances. Are disqualifying factors both on original examination and in the pilot because founded on either a hysterical or organic basis.

(8) Dreams. When frequent or disturbing in character they indicate a high degree of maladjustment due to inadequate handling of conflicts during the day—hence a poorly recuperated organism.

The ability to maintain pleasant relations with his associates and the freedom from financial, family and social difficulties is essential.

NEUROLOGICAL EXAMINATION

Pupils. Carefully observe size, equality or inequality, and outline. As to size, whether normal, miotic, or mydriatic; in comparison whether equal or unequal; and as to outline, whether round, or if otherwise whether due to disease or operation. Reactions to light and accommodation to be observed with utmost care; particularly whether the reaction to light is normal, slowed, diminished, or lost. Any pupillary abnormalities to be interpreted as significant of luetic infection, and requiring clinical as well as serological proof of the absence of such infection. Look also for ptosis and ocular muscle palsies.

Deep tendon reflexes. Classified as absent (0); diminished (-); normal (+); hyperactive (++) ; exaggerated (+++). Abnormalities to be interpreted as significant for neurocirculatory asthenia, psychoneurotic disorders, lues, organic diseases of the cord, and so forth; the genesis, therefore, to be clearly established.

Station. Examinee to stand with knees pressed back; arms hanging loosely, eyes closed, and inner margins of feet in apposition. Interpretation of abnormalities to be clearly stated.

Gait. To be carefully observed as examinee, with eyes open, walks forward and backward along chalk line or crack in floor, and repeats with eyes closed; walks in circle with eyes open, and repeats with eyes closed. Interpretation of abnormalities to be clearly stated.

Tic. Name part or parts affected; and as to degree, whether or not tending to incapacitate or make conspicuous.

Tremor. State whether fibrillary, fine, or coarse. Name part or parts affected; and state whether of the intention or continuous type.

Other motor factors. If abnormalities are observed, state type, part or parts affected, and cause.

Psychomotor tension. To be interpreted in terms of ability or inability voluntarily to relax. The examinee rests his forearm, with utmost relaxation,

in palm of examiner's hand. With the unexpected removal of the examiner's supporting hand, examinee's arm does or does not drop naturally to his side.

Peripheral circulation. Examine for flushing, mottling, and cyanosis of face, trunk, and extremities. Question concerning the presence of localized sweating (axillae and palms), and cold extremities. Such symptoms denote neuro-circulatory asthenia which is disqualifying.

The finding of any of the following in the physical examination should cause disqualification according to Longacre.

Unsatisfactory physical examination. Disproportion between height and weight; abnormal distribution of adipose and muscular tissues; (as indicating endocrine disturbances); pallor, cyanosis, or congestion; (indicating circulatory disturbances); posturing; abnormal movements; facies indicative of abnormal intellectual or emotional reactions. Pupils abnormal in size, irregular, unequal, reacting improperly to light and accommodation; Argyll-Robertson pupil; abnormal ocular movements, particularly nystagmus; (in examining the pupils make certain any abnormalities observed are not due to miotics, mydriatics, cycloplegics, or drug addiction); abnormal station, gait, and reflexes; disqualifying ties and tremors, deformities; paralyses; trophic disorders; tuberculosis; other respiratory disorders (if chronic); spinal cord diseases; organic brain diseases; history of convulsions, vertigo, aphasia, disturbances of speech or sensation. Abnormal cerebrospinal fluid findings and electric reactions.

By the time this examination is completed a pretty complete survey will have been made of the personality as to temperament, intelligence and volition. The following traits are found in the optimum type for flying.

Personality showing

Temperament. Cheerful, stable, self-reliant, aggressive, modest, frank, fond of people, satisfied, punctilious, serious, good coöperation in work and in examination, good sportsmanship, moderate tension, enthusiastic, adaptable.

Intelligence. Precise, penetrating, sharp, alert, resourceful.

Volition. Energetic, quick, deliberate or moderately impulsive, controlled, good tenacity of purpose.

The following traits denote an unfavorable type.

Temperament. Depressed, unstable, submissive, pacific, vain, withholding, secretive, loquacious, likes to be alone, hypercritical of conditions, careless, frivolous, poor coöperation, irritable, poor sportsmanship (under adverse circumstances querulous and complaining), exceedingly high tension, lost enthusiasm.

Intelligence. Vague, superficial, dull, hesitant, without initiative, untrained.

Volition. Sluggish, slow, recklessly impulsive, restless, poor tenacity of purpose.

The same author further states,

It is not expected that any one aviator will exhibit all the best qualities to the exclusion of all the poor ones, but the preponderance towards a favorable or unfavorable, satisfactory or unsatisfactory, efficient or inefficient type, will lead to an accurate estimation of the efficiency and true personality of the aviator.

Definite psychotic personality traits may be uncovered in the course of the examination and if they are they should be considered absolutely disqualifying. Longacre discusses these traits as follows:

Seclusive including persons described as abnormally quiet, reserved, timid, shy, bashful, retiring, secretive, self-absorbed, preoccupied, unsociable, averse to meeting people.

Over-active. Including persons described as abnormally over-active, unusually mentally and physically aggressive, talkative, unduly optimistic, tendency to exaltation.

Depressive. Including persons who are worrisome, gloomy, easily discouraged, inhibited, restrained, unable to make decisions.

Unstable. Including persons subject to marked emotional oscillation, either up or down in mood, easily elated or discouraged, unsteady, changeable.

Suspicious. Including persons abnormally mistrustful, sensitive, prone to see sinister meanings in indifferent occurrences, inclined to misinterpretations, who feel discriminated against.

Egotistical. Including persons described as high tempered, easily annoyed and angered, subject to irascible, explosive reactions; on slight provocation, abusive and cruel.

Sexually abnormal. Including persons with sexual perversions and inversions.

Criminalistic. Including persons with anti-social traits, history of various major and minor offenses.

After our examination is completed, we may review the examination as a whole and make up our minds as to whether the candidate should be qualified, disqualified, or whether he should be kept under further observation and study.

Where there is doubt in the mind of the examiner as to which class the candidate belongs in, he should require further observation and study. Evidence of staleness and a history of recent and remediable unsatisfactory conditions is an instance. Recent depression, recent and immediate worries, temporary, financial, family or social difficulties, conflicts recent in origin and capable of satisfactory solution are examples of the factors that will place a candidate in that class. He should be held there until his condition warrants either qualifying him or disqualifying him.

A personality study is like any mental examination and his past history and present conditions are investigated, both to show his reactions to his environment in the past and to enable the examiner to prophesy his probable reactions in the future to his environment as a flyer.

Amsden (1) states that

It is plain that a study of the personality may be approached from at least two points of view. No one is prepared to act wisely upon his estimate of a personality who does not reckon with the phylogenic components of it. On the other hand, no one is able to act wisely upon an estimate of the personality who does not also take into consideration those determinants which have arisen in the efforts of the individual to mobilize his endowment and to train it upon the problems with which his own environment and his own nature have faced him.

Again, in the same paper he states, "A statement or summary of a personality would, therefore, attempt to indicate the reactional assets and liabilities of the individual in such wise that an insight is gained into the probable general course of action he would under given circumstances follow."

Rippon and Manuel (7) agree pretty much with the foregoing. They claim that the traits of character desirable in the flyer are resolution, initiative, presence of mind, sense of humor, judgment, alertness, cheerfulness, optimism, and not too much imagination. They believe the best pilots are unmarried and consider marriage as an extra nerve strain. They consider a sedentary occupation as being unfavorable. They lay great stress in manual dexterity and consider that a good horseman will make a good pilot.

Flack (2) places reliance on the history of indulgence in sports as evincing training in coördination. He lays stress on tests for neuro-muscular coördination and nervous stability. The self-balancing test and the balancing rod tests are described in the next chapter. He looks for tremor and for the character of the reflexes. He considers that exaggerated reflexes alone are of no prognostic value. If marked tremor and poor equilibration both occur, he considers the candidate unfit for air work. Both are considered signs of poor neuro-muscular stability. If he presents one of these signs, he should be considered carefully and the chances are against his making good.

The practical significance of this work may be gained by reading the following case histories which were collected by Longacre.

Lieutenant X had his training in 1918. One day in 1920, while at about 10,000 feet, his head was turned sharply to the right as he studied the landscape beneath, this for perhaps thirty or forty seconds. On sitting erect and facing forward there was blurring of vision with black specks and immediate fear of fainting,—although he does not believe that he actually fainted. In a panic he shouted to the observer to place his stick and dived about 2000 feet. He believes the downward rush cleared his head and he circled about, but again had feeling of fainting and landed at once. He reported the occurrence to the flight surgeon and says he continued to fly but ever afterward was fearful of fainting. In April, 1923, while on cross country again had fainting feeling, returned to his station, reported to the flight surgeon, and was made an observer. Says has no fear of fainting since being an observer but is averse ever to taking the stick again.

When about eight years old he fell about 15 feet striking his head on the pavement, had concussion, and was unconscious about four days. Between his ninth and fifteenth years he fainted in his seat in church on at least three occasions. During his training period in 1918, and having had ten hours in the air, he was practising hopping a tree on the border of the field, struck the tree-top, and had a complete "wash-out." He climbed out of the wreckage, lit a cigarette, conversed with the by-standers, and then walked to the ambulance and was taken to the hospital to have his wounds dressed. He explains he was told he did these things but has no recollection whatever of what occurred. There is complete amnesia for a period of about one-half hour—he recalls seeing the tree-top and then of being in the hospital. Significantly, the disturbing thought ever afterward was, "Did I check speed so much that the ship dropped, or did I faint—the latter, especially, in view of my fainting record?"

Recently, at the School of Aviation Medicine, a flyer who had been examined elsewhere a number of times, was shown to be at least a potential epileptic and probably a true epileptic. This man gave a history of enuresis up until nine years of age, of stammering from nine to twelve years, of somnambulism from twelve to fifteen years, migraine with an attack of hemianopsia from fifteen to twenty years of age. When about twenty, in getting out of bed he fell and struck his head and remembered nothing until about two hours later when he said he felt sore all over. It is evident that the examination made at the School is the first careful neuropsychic examination this officer has ever had, else this condition could not have gone so long unrecognized.

One day at ——— Field Captain Z, an experienced pilot, was going into the air as a passenger. He had just returned from sick leave and had not yet been given the special examination required to be given in all such cases before the pilot is authorized to fly a ship. Presumably it occurred to Captain Z that he might, during the ride, have opportunity to take the control. In any event, he obtained a stick and placed it in position in the rear cock-pit. The pilot took off and when a few feet up found he could not move the stick the required distance. The ship crashed and the pilot sustained a fractured jaw. Captain Z was not injured. On inspection it was found that the stick the latter had placed was in reverse position, thus accounting for the fact that the pilot could not move his stick as required. Immediately Captain Z fell under the presumption of having been guilty of gross carelessness, but the possibility of

some abnormal condition having arisen being conceded, he was sent to the School for examination. The following history was obtained.

After the War Captain Z was ordered from ——— Field to service in Germany. About one month after arrival there he was in the air as a passenger when the pilot crashed. Captain Z sustained a severe head trauma, had concussion, and was in hospital a long time. Nearly a year later he was ordered to a general hospital for observation and treatment. There was amnesia reaching back to his departure, one year before, from ——— Field and down to the latter part of his return voyage. He recalled his departure from ——— Field but could not tell how he reached Germany. He could partly describe the pilot with whom he rode to the crash but could not recall his name. In addition he could tell of a few widely separated incidents connected with the period in Germany, that is, there were islets of memory. He could not, however, recall his departure from Germany, the Continental journey, or the port from which he sailed. Memory began to return when about half way across the ocean, became more and more clear, and was fully restored by the time he reached the hospital. After some time in the latter hospital he was declared fit for duty and reported at ——— Field.

Captain Z had been at ——— Field nearly one month and the flight surgeon knew, as is expected he should that the Captain had come to be regarded as an inefficient officer. During the examination the Captain said he had believed himself fully recovered when he left the hospital but wondered in view of his experiences since, whether the assumption had been warranted. He remarked that his work had been easy, yet he frequently felt excessively fatigued without adequate cause. For instance, while sitting at his desk of a morning there would be such weariness, that regardless of what the situation might be he would feel compelled to go to his quarters and lie down for a half hour or more. The examination now proceeded along more definitely psychiatric lines and an anxiety neurosis trend was clearly revealed. The special manifestations were: frequent and terrifying dreams of occupational type, that is, of air accidents; apprehension concerning flying duty as well as any other duty; memory defects; irritability; inability to concentrate; tics; tremors, relaxed peripheral circulation; lowered psychomotor tension; and feelings of self-depreciation and insufficiency expressing an inferiority complex completely unsublimated—no effort at compensation—a defeated psyche. In view of the prolonged amnesia from which he had so recently emerged and the tragic error in placing the rear seat stick, there was need of establishing the presence or absence of recurring minor equivalents in the form of unobtrusive memory lapses or automatisms. In these directions it was clearly shown that the Captain, at various times since being at ——— Field, had found himself sitting at his desk or standing some place and wondering how long he had been there. These manifestations were interpreted as lapses of memory, momentary or longer; and the condition or state obtaining at the time of misplacing the stick a disturbance in consciousness analogous in kind.

Captain Z was returned to a general hospital and after a period of observation retired for disability.

Again Longacre (3) states:

Any psychiatrist will concede the special interest attaching to cases such as the foregoing. But to the flight surgeon the interest is special, it is vital—lives are at stake. Neither perfunctory and routine methods nor superficial knowledge will suffice for these examinations. There must be painstaking investigation of the whole life history and exposure to view of the total experience, combined with well grounded psychiatric training, in order to meet the requirements.

SUMMARY

To summarize, heredity is important because it may tell us of an inherited instability. Personal past history is important because it may bring out history of syphilis, epilepsy or encephalitis, and because by reviewing the entire life from infancy on we have before us the physical and emotional life history of the individual including a survey of his temperament, intelligence and volition. We see how he has reacted to the various crises, stresses and strains and what scars have been left in his mental makeup. We can then form an idea of how he will react to the stress and strain of flying. Deeply seated worries and mental conflicts inadequately handled, result in a disturbance of the mental equilibrium; a complex—unless properly sublimated shows inherent instability; phobias show a psychoneurotic taint; excesses show instability; the past history will bring out a lack of adaptation to environment and circumstances, the neurological examination will bring out not only organic defects but also instability of the type of neurocirculatory asthenia, as shown by exaggerated reflexes, the presence of tics, marked tremors, increased psychomotor tension and relaxed peripheral circulation.

Individuals who show any of the defects or tendencies listed are to be regarded as poor risks and when the more serious defects or tendencies or a number of minor ones are found, the candidate must be rejected, as these defects and tendencies are bound to become accentuated and affect seriously the pilot's progress and efficiency.

Again to quote Longacre (3), the examination, to make a satisfactory forecast of the flyer's reactions to flying must

reveal latent tendencies which under the stress of flying might become so accentuated as to make him inefficient and lead to nervous and mental breakdown; or on the other hand, make clear such stability of organization as will be proof against stresses admittedly exceptional and foreign to average experience. It is not conceded that nature has at last achieved her highest objective and in the flyer produced a superman. It is, however, required that he be equal to the requirements of any situation, usual or unusual, and with respect to the unusual, be capable of the instantaneous and correct response demanded by the emergency.

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CHAPTER V

REACTION TIME

In the previous chapters we have discussed the qualities necessary for the average flyer from both physical and mental standpoints. After we have selected our group of individuals who show no mental or physical deficiencies which would disqualify from flying, we find from practical experience that a large number of these men will not qualify as flyers. There must be something, then, besides the purely physical and mental factors which go to make up a successful aviator. Various theories have been advanced, much experimental work carried out and tests devised to determine this unknown factor. There is no question but that quick reaction to a given situation is desirable, in fact, necessary to the flyer. It would seem, therefore, that a reaction time test is indicated. Most examinations prescribe one or more reaction time tests. The examination for the United States Air Service does not prescribe such a test and it is believed this is the weak point of our examination. However, the author knows of no satisfactory test at the present time. He does not feel that the tests used by the French and Italians give the results that are desired.

In flying the pilot is called upon to make rapid mental decisions. These decisions must be followed by complicated movements of hand, arm and foot, as practically any movement of the plane requires movement of both stick and rudder.

In learning any new process, which involves a complicated act there are definite periods in which there will be a falling off in the rate of improvement. Dockeray states (4) "It is well known to psychologists that in the acquisition of any complicated act of skill, there are often definite periods of lapse in improvement due to certain difficulties in adjustment of the organism and also to the change in the attitude of the learner."

Spurrell (14) states that in learning to fly a man should work out in his higher centers what must be done, then train his muscles to do it and then turn over the controls to his reflex centers. He states that in the education of the nervous system, the first stage is the cerebral

stage in which everything is done by conscious mental and muscular effort. The second stage is the transitional stage in which conscious and unconscious nerve centers are competing for control and the third or final stage is that of instinctive flying.

In devising any test the above must be taken into consideration.

FRENCH TESTS

Maublanc and Ratié (9) state that they found the opinion among experienced pilots is that of every hundred persons without gross physical defects, only one-half or one-third would become pilots. Our own experience in the United States has been that only about 25 per cent of those who are selected for cadet flying school eventually graduate from advanced flying school. Unquestionably the proper care in making the neuro-psychic examination would eliminate before enrollment a great many unsuccessful candidates; even so, it is doubtful if more than 50 or 60 per cent at the outside of those selected by our physical or mental standards described in the previous chapters would qualify as successful pilots. Maublanc and Ratié (9) describe the tests used by them in the French Air Service which are modifications of those originally described by Camus and Nepper. They measure the psychomotor reaction times by means of a d'Arsonval chronometer. Reaction time for visual, auditory and tactile impressions are recorded in hundredths of a second. The visual test is a light, the auditory an electric bell and the tactile the touch of the hand. When the stimulus is felt the subject presses a key which breaks the electric circuit. They found the average reaction time to visual stimulus was 0.19 second, to auditory stimulus 0.145 second and tactile stimulus 0.14 second. Ten tests are made for each and the average taken. Marked variations show instability. They found that age caused reaction time to become slower and disease modified it markedly, likewise fatigue. Doubtless the tests described are excellent psychological tests for determining reaction time for visual, auditory and tactile stimuli *of the sort used in the tests*. However, our experience has been that there is nothing to indicate that because the individual shows quick reaction on seeing a light flash, hearing a bell ring, or feeling his hand touched by a plate, that he will react promptly with the complicated movements of hand, arm and leg necessary to adjust his plane when in, for example, a spin or when required to make a sudden change of direction in combat. The two are entirely different.

ITALIAN TESTS

The Italian tests were described by Gradenigo (7) Gemelli (6) Azzi (3) Aggazzotti (1) and Romagna-Manoia (12). The Italians use a simple reaction time test for visual and auditory stimuli. Reaction times are recorded with a chronoscope, the stimulus for visual reaction being a green diaphragm lighted by a 2 candle power lamp, for auditory a lever falling from a fixed height and striking a key. The reaction times were found to be practically the same as those described by the French. They also describe choice reaction time tests. Choice reaction times are made with the right or left hand in any of four directions and combination reactions with hand and foot are made. Five 16 candle power lamps are arranged in a frame, two upper, two lower and one in the middle. Underneath is a small check lamp. There are two keys on the table for the hand and two under the table for the feet. The subject is required to react to any light or combination of lights and may be called upon to react to any two lights simultaneously. The check light shows whether or not the reaction is correct. Choice reactions are also tested by movements of a vertical lever like the control stick of a plane which the subject moves in any of four directions according to the direction indicated by a lighted arrow. Emotional reactions were studied by adjusting rubber tubes, one to a double pad over the common carotids, one over the chest, one over the right hand and another to a glass tube in which the left forearm is inserted. The tube is filled with water and a kymograph drum started revolving. Needles attached to the rubber tubes record the pulse of the carotid, respiration, tremor of the right hand and level of vaso-motor tone in the left forearm. A sudden terrific noise is then made behind the subject causing all needles to jump. If the needles quickly return to normal level it shows no abnormal disturbances. Where the return to normal was not immediately made, records show rapid pulse, increased respiration, and drop in vasomotor tension line, all evidences of shock. About 13 per cent were disqualified by this test as excessively emotional.

The combination reaction tests and choice reaction tests are perhaps of more value but the simple reaction tests are of course subject to the same criticism as are the French tests. Even the more complicated tests are hardly indicative of the subject's probable reaction to the condition of flying.

BRITISH TESTS

Anderson (2) describes the original tests of Camus, Nepper and Binet, as used in the British Air Force. The visual reaction time consists of a d'Arsonval chronometer, worked electrically, having a clockwork movement, with a dial divided into 100 parts and a speed of one revolution per second. The examiner holds one press button switch and the candidate another. To measure visual reaction time the examiner starts the pointer revolving by pressing his thumb switch and when the candidate perceives the pointer moving he stops it by pressing his thumb switch. The time is noted. Auditory reaction time is tested by the examiner tapping with a thumb switch on the table. The present regulations provide for the use of an electric bell for the auditory test. This starts the pointer to move. When the candidate hears the tapping or the bell, he stops the tapping or indicates that he has heard the bell by pressing his thumb switch. The tactile reaction time is measured similarly, the examiner tapping the candidate on the head or hand and when this is felt the candidate again presses a switch. The present regulations provide for the use of an electrode. Reaction times were found practically the same as those reported by Maublanc and Ratié.

The emotional reaction time was tested by fastening a pneumograph around the candidate's chest, placing a trembler in his left hand and fastening a pneumatic pointer around two fingers of his right hand. All three were connected with stylets on a revolving drum. The effect of a magnesium flare or a revolver shot was then recorded. In good candidates the emotional reaction was of short duration. The criticism made of the tests of Maublanc and Ratié apply in the same way to these tests with the exception of the emotional reaction time. It is probable that a careful neuropsychic examination will bring out emotional instability much more satisfactorily than reaction time tests of this sort.

The British in the early days, used the MacDougal test. In this test there is a machine which sends out a ticker tape with circles on it. The subject is supposed to touch the center of the circles with a pencil. The rate of movement of the tape can be regulated. It was found that the performance could be improved by the administration of oxygen. Another emotional test which they used formerly was that of having the candidate draw a line lightly and deliberately across the long way of a sheet of foolscap, parallel to

the border, without letting the hand touch the paper. Presence of tremor is thus noted. He is asked to draw a second line and while drawing it an unexpectedly loud noise is made close to his ear. A third line is then drawn after the subject is warned that the noise will be again made. In the sound individual there is either no interruption in the line or only a slight irregularity at the time of the noise. The nervous individual either makes a sudden dash or the line is continued in a shaky manner.

Two tests still in use in the Royal Air Force (10) are the following. The first, known as the self-balancing test, consists in having the subject stand at attention with heels and toes touching. He then flexes one knee to a right angle, being careful not to support it against the other leg, closes his eyes and endeavors to maintain this position for fifteen seconds. Three attempts are allowed. The number of attempts necessary and the manner of performance, namely steady, fairly steady or unsteady, are recorded. The other test is the balancing rod test. A balancing rod is placed upright on a board about $1\frac{1}{2}$ inches from the forward end. The candidate takes hold of the board between finger and thumb and endeavors to raise it at arms length from the table to the level of his shoulder and back to the table without upsetting the rod. The test should be performed first with one hand and then with the other. It should be performed equally well with either hand. It is the author's impression, gained from conversation with Group Captain Martin Flack of the Royal Air Force, that the self-balancing test and the balancing rod test are considered useful tests but that not much confidence is placed in simple reaction time tests. The British are now working on a new test which gives promise of something of value. The test was devised by Flight Lieutenant Reid (11) of the Royal Air Force. The apparatus consists of an old Avro which has been fitted with a Reid control indicator. When the control stick and Reid bar are not in neutral an electric current flows through a Morse telegraph machine and clock reading to a hundredth of a second. When the controls are again in neutral this stops the flow of current to the machine and clock and they stop. When the current is flowing in the circuit, the Morse telegraph machine causes a strip of paper to run under a small roller inked with red ink. The marking starts when the machine starts and continues until the machine stops. The machine is placed in a spin or turn and the length of time it takes to right the machine is thereby measured. If he overcontrols, this

is recorded also. Behind the pilot's seat is a Klaxon horn and the examiner blows the horn during the test and thus measures the reaction to an added disturbance. The strips of paper are then pasted side by side on a large sheet and a line drawn connecting the end of the red marks, giving a graphic description of the pilot's reactions. Trained pilots will show reaction times entirely different from those of untrained pilots. Untrained individuals may also be grouped according to their reactions. It is believed that this apparatus offers a possible solution to our difficulties in finding a test which is a reaction time test of the sort of reaction which the pilot will have to make in the air.¹

AMERICAN TESTS

The Ruggles orientator which has already been described in a previous chapter is felt to offer even better opportunities than the Reid Control indicator. In this apparatus the candidate can be placed in any position and the reaction time from the time he is placed in that position until righting the machine can be measured. It has the added advantage of placing a man in various positions with respect to his environment, whereas in the British machine the candidate's position is unchanged, but merely the controls shifted. Work which was done at Brooks Field Primary Flying School during the winter of 1923-1924 indicates that this sort of test would prove very valuable. During this period a large number of students were given orientator training along with flying training. It was found that men who reacted poorly on the orientator had difficulty in learning to fly. It is believed, therefore, that if reaction time apparatus could be hooked up with the orientator and statistics collected on a large number of pilots and candidates, a test could be evolved which would determine to a large extent an individual's flying possibilities.

Dockery and Isaacs (5) made a study of the tests used by the Italians, French and British. They examined three groups of Air Service officers overseas, these were moniteurs of the instruction center at Issoudun, chasse-pilots from the front who passed through Is-

¹ Group Captain Flack and Lt. Reid kindly showed the author some of their very interesting results, but as they have not yet been published, the author does not feel at liberty to discuss them here. He has given this brief description of the apparatus, as it has been on public display at Wembley, is patented, and, therefore, protected.



FIG. 15. THE RUGGLES ORIENTATOR ON THE FLYING LINE (COURTESY OF W. G. RUGGLES)

soudun on their way home, and observers from the front who returned through Tours. Only those who were shown to be exceptional flyers were examined. All subjects were given a thorough Air Service physical examination first and all those who showed any factors that might influence the results of the psychological test either from a physical or emotional standpoint were considered specially. In the case of the pilots, the standard and simple reaction time to visual, auditory and tactual stimuli and a steadiness test were given. The observers were given a rebreather test and a new test devised by the authors which will be described later. The results of these tests were compared with the flying rating given the officers by the training department. The French reaction time tests were those that were used.

The French found that the mean reaction time for the visual stimulus was 0.19 second and 0.14 for the auditory stimulus. A tenth of a second lengthening was considered sufficient to bar the candidate and a tenth of a second was considered the maximum deviation for the individual from his own mean reaction time. They found a somewhat higher mean than the French and that there was a wider variation, not only between individuals but also between separate reaction times of each individual; for example, their mean visual reaction time was 0.197 and the auditory 0.155 and tactual 0.143s. Classifying them according to their work, the moniteurs had a mean visual reaction time of 0.189 and the fit chasse-pilots 0.197 and the unfit chasse-pilots 0.205s. They found that the correlation between the training department rating and the average reaction times was low. It was slightly higher in the group reported as fit than it was in the total group; for example, in the visual reaction time the correlation was 0.051 for the total group and 0.113 for the fit group. In the auditory reaction time, the correlation was 0.095 for the total group and 0.132 for the fit group. It was 0.075 for the tactual reaction time and 0.037 for the fit group.

Based on this, Dockeray and Isaacs state,

It is very doubtful, in our opinion, however, that the simple reaction time can be regarded as an adequate test in the selection of aviation candidates. It is possible that more complicated reaction experiments, such as those that involve discrimination of varying degrees of difficult judgment and other modes of association may yield important results.

A steadiness test was carried out as follows:

The apparatus for the steadiness test consisted of a sheet of copper about $\frac{3}{2}$ inch thick and 6 inches square in which holes were drilled $\frac{1}{8}$, $\frac{1}{4}$, $\frac{3}{8}$, and $\frac{1}{2}$

of an inch in diameter. This plate was attached by one corner to the window sash and could be turned up or down sufficiently to bring any hole on a level with the eyes of the subject when he stood erect. It was connected in series with a dry cell, stylus and signal magnet, adjusted to mark upon the smoked paper of a kymograph revolving once in a little over one minute. The subject was instructed to stand erect with the right arm free from the body, but in as easy a position as possible, and with the stylus held horizontally between the thumb and fingers as he would hold a pencil in writing. He was to take his time in inserting the stylus into the hole and was further informed that no record would be made until he had fairly done so. He was to hold it in the hole without touching the sides for a full minute. He was warned against holding his breath, as this would interfere with his steadiness before the end of the minute, and quiet regular breathing was recommended. The largest hole was used first. After the subject had rested about half a minute the next smaller hole was used, and the other two holes in the same manner.

One hundred twenty-eight subjects were examined and were divided into five groups on the basis of the appearance of tremor. Group one showed fewest contacts and group five practically continuous contact. Groups one and two were considered together and groups four and five were considered together. The index of correlation between the training department rating was found to be 0.725 ± 0.181 . They found this result to agree with Head's statement that "Tremor is not so much an indication of a neuropathological temperament as of a definite disturbance of function."

Dockeray and Isaacs (5) devised a test for observers based chiefly on one of the duties of an observer, that one being visual reconnaissance. The duties of an observer on an airplane reconnaissance mission are, to note movements of troops behind the enemy lines, location, number and nature of transports, railroad movements, detraining, ammunition, rolling stock, airdromes, their location, number and activity, location of camps and bivouacs, usually discovered by tracks and smoke, fires, etc.; activity in villages and towns behind the lines, lines of defense, location of batteries, new construction, aerial activity, hostile balloons, anti-aircraft artillery, etc.

The test was devised on the principle that it might reveal "individual differences in the quickness, accuracy and certainty of the observation of a situation, requiring definite study, especially of the nature and relation of parts, in its recall, and in its recognition when again presented." The test was applied to about fifty observers returned from the front.

Dockeray (4) believes that one of the most important factors to

be investigated is the emotional stability. He states that following the sudden plunge of the plane in an unexpected direction, the flyer not only loses his balance, but that he has changed his position in relation to the earth by several hundred feet in a very few seconds. He goes on to state,

The rush of air, the abnormal pressure upon his viscera, and the loss of the direction of gravity, are capable of creating all the conditions of a violent emotion, which, if not checked quickly, become worse, and the aviator may lose all consciousness. There is no doubt that in many of the cases in which an aviator has been observed to dive or vrilie a thousand feet or more to his death without an apparent attempt to right his machine, this condition has been responsible for his catastrophe. It seems, therefore, that emotional stability is one of the important problems to be investigated.

Dockeray (4) believes that the nervous, high strung or those bordering on the temperamental type are the least reliable. While they become good flyers, no great reliance can be placed upon them as they are liable to become psychotic on distress.

GERMAN TESTS

Kronfeld (8) devised a test which he based on the fact that flying demands,

Accurate observation, quick and correct comprehension, sustained readiness to react, presence of mind, sureness, repose, motor exactness, a concentration incapable of being diverted from the task at hand through all possible distractions. There must be a capacity to learn, a practice effect with little fatigue, the ability to alternate the attention rapidly and to carry on several tasks at the same time. Optical stimuli were considered more important than acoustical.

The candidate had several tasks to perform, one chief, the others secondary. In front of him a panorama rolled by which represented a landscape from a perspective of 2000 meters. On this were designated a series of 30 artillery stations. This landscape was mounted on a kymograph drum and so could be presented continuously. A complete revolution was made every two minutes. The candidate observed this landscape through a sighting apparatus and his task was to "photograph" the artillery stations as they passed by a midline by pressing a reaction key. This constituted the chief task.

As a secondary task, he had to react to different colored lights which were flashed on around the central field of vision. For lights on the left, the right key had to be used, for lights on the right, the left key. The key had to be pressed once for a white, twice for a green and three times for a red light.

Another secondary task consisted of listening to the sound of a motor and indicating by a call when the sound changed.

As a visual distraction, a sudden flash of light immediately behind the observer was introduced at the beginning of the eighth minute.

Reactions to the artillery stations and to the lights were recorded on a kymograph drum. The experimenter marked on the drum the time of acoustical stimuli and of the visual distraction. Auditory reaction times were not measured.

After practice in observing the artillery stations and reacting to the lights separately, the test was begun. For four minutes, the candidate had only to observe the landscape and react to the artillery stations, then the secondary tasks were introduced and the test continued for ten minutes. Thus, a measure of the effect of complicating the task was obtained. At the eighth minute, the visual distraction occurred.

The system of scoring the various results as worked out was purely arbitrary and the score determined above which an individual would be considered unsatisfactory for flying service. He found results correlated very well with the aviation history of the candidate.

Stern (13) describes a psychological test carried out at the University of Strassburg. At first separate tests were used for attentiveness, memory, quickness and sureness of movement, capacity to withstand fatigue, timidity, ability to orientate oneself, capacity to discriminate between similar optical stimuli and finally ability to observe competing fields of view (Kronfeld's test).

He also tested them by means of one complicated test. As a result he concluded that the complicated test gives more reliable results. He revised and improved this test and his later test is as follows:

The observer was seated in the middle of a darkened room before a table which was rigged up with a series of levers. The ceiling and forewall each contained a series of electric lamps. The lamps on the ceiling were in metal housings which had forms cut out on the side toward the observer. These forms of two kinds, were similar to one another and represented the French and German ships. The size of the forms varied somewhat and the lights were of different colors. The lamps on the forewall were also in metal housings; these had varying numbers of point-formed holes bored out on the side toward the observer. Furthermore, a strip representing land upon which artillery stations were marked rolled by on the floor; this strip was lighted by an incandescent lamp so that the stations in passing were visible as distinct points. A sound hammer and an electric clock were also part of the equipment.

The table before which the observer sat had six levers mounted vertically so that they could be turned forward or back about 90 degrees until they touched the table and made an electrical contact. The observer used the three right levers with the right hand, the three left with the left hand. The two outer levers closed the circuit only if a contact was closed with the cor-

responding foot. Lamps could be lighted by the experimenter, singly or several at one time. A reaction had to follow only the presentation of lights showing the French ship, while to the German there should be no reaction. For each lamp a special lever movement was designated; for every sound hammer stimulus, lever 4 had to be moved forward; for every artillery station appearing on the strip of land, lever 4 had to be moved backward. A Hipp chronoscope in the circuit measured all reaction times to the light stimuli. Reactions to the artillery stations were recorded by a marker on a kymograph drum.

The observer was instructed to imagine that he sat in an air ship. The analogy of the tasks to those of flying was pointed out to him in each case, then he was allowed sufficient practice to learn which movements corresponded with their respective stimuli, after which followed the first part of the test lasting twenty minutes. In the second part of the test another task was added, namely, that of counting the lights as they appeared on the forewall. This lasted for ten minutes, as did the third part, in which the comparing of the number of points of two successive lights was substituted for the counting. In all instances, false reactions, failure to react, and reaction times were taken account of. The effect of distraction as shown in parts 2 and 3 was also considered.

Summarized, therefore, it can be stated that aside from the possibilities of Reid's machine and the Ruggles Orientator we have no reaction time test for pilots which is of any practical value. These two apparatuses have not as yet been sufficiently tested in this regard to make a definite statement about them. The tests of Isaacs and Kronfeld have possibilities as tests for observers. It can be said, however, that there is great need for such a test as shown by the fact that only 25 to 50 per cent of those who meet physical and mental standards ever make flyers. Experience indicates that this large per cent of failure is due to delayed reaction time.

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SECTION II

THE PHYSIOLOGY OF AVIATION INCLUDING
THE CLASSIFICATION OF THE FLYER

CHAPTER VI

THE EFFECTS OF ALTITUDES ON THE RESPIRATORY AND CIRCULATORY SYSTEMS

At the onset of the world war, the only information we had regarding the effects of altitude was that obtained by expeditions to and investigations on high mountains. Any interest man had was from a purely scientific standpoint. The development of aviation during the war resulted in flights being made at increasingly high altitudes, combat work towards the end of the war being carried out at altitudes of eighteen to twenty thousand feet. It is said that during the next war, combat work will be carried on at even higher altitudes. Consequently, the effects of altitude have become of practical significance to those of us who are associated with the Air Service.

Before taking up in detail the effects of high altitude on different body functions, it will be worth while to review the normal physiology of respiration and circulation. An average normal individual breathes approximately 18 times per minute and the total volume of respiration is approximately eight liters. Assuming the subject is at sea level, he is then breathing air containing approximately 21 per cent of oxygen, at 760 mm. Hg barometric pressure. Atmospheric air absorbs 47 mm. water vapor pressure by the time it reaches the depth of the lungs, and this 47 mm. must, therefore, be deducted from 760 mm., giving us air in the depths of the lungs at a pressure of 713 mm. Hg. There is a reduction of oxygen percentage from that in the atmosphere to that in the alveoli (due to dilution by the residual air of the lungs) of one fourth or even one third. We have, therefore, an oxygen percentage of 14 to 15 and an oxygen pressure in the alveoli of 103 mm. on the average. Alveolar air is brought in contact with the lung capillaries. Under normal conditions the oxygen pressure in the alveoli is greater than that in the blood stream. The oxygen is therefore absorbed from the alveoli into the blood. This blood takes up oxygen by means of hemoglobin in loose chemical combination and also in solution in the blood plasma. The blood is exposed to air in the lungs over approximately

100 square meters of lung surface. At rest the whole blood volume passes through the lungs about once per minute; during violent exercise it may pass as often as ten times a minute. One hundred cubic centimeters of blood can carry 18.5 cc. of oxygen. Of this, 0.24 to 1 cc. is in solution in the plasma and the balance in loose chemical combination with the hemoglobin. The amount of oxygen dissolved by the blood depends upon the partial pressure of the oxygen in the alveolar air, the temperature of the blood, the concentration of salts in the blood and the H-ion concentration of the blood. The following laws apply to the absorption of oxygen: Henry's Law: The absorption of a gas by a liquid varies directly as the pressure. Law of partial pressure: If a liquid be exposed to a mixture of gases it will absorb each gas in the proportions in which it exists in the mixture. Therefore, the percentage of the gas in the total mixture multiplied by the barometric pressure, under which it is, determines its partial pressure. For example, the partial pressure of oxygen in sea-level atmosphere is, 760 (mm. barometric pressure) $\times$ 20.96 (percentage of oxygen in the air) = 159.3 mm. Under normal conditions temperature does not play a great part but it does under exercise and febrile conditions. The law is that absorption of gas by a liquid varies inversely with the temperature. The quantity and quality of the salts vary in different species of animals but in men under normal conditions difference in salt content of the blood is so small that we may disregard it.

There is a chemical ratio maintained at all times, under normal conditions in the blood plasma between the carbonic acid and the sodium bicarbonates. This is expressed by the fraction $\frac{\text{H}_2\text{CO}_3}{\text{NaHCO}_3}$.

An effort is made to keep this fraction constant. When either numerator or denominator increases or decreases, the other is likewise increased or decreased. The normal proportion is approximately 3:60. The source of these substances is as follows: The CO_2 is received from the tissues and the sodium is derived from the protein and from the sodium chloride. The blood, after it receives its oxygen supply, carries it to the tissues. Some of the oxygen, about 5.5 cc. per 100 cc. of blood, under resting conditions is then given off by the blood to the tissues. The amount given up depends on the needs of the tissues, the remainder being transported back by the venous blood. The venous blood contains approximately 13 cc. of oxygen to every 100 cc. of blood. The dissociation of this oxygen

from the blood likewise depends upon the same factors which influence its absorption. High temperature, as seen in violent exercise, results in more oxygen being dissociated. The individual may also by training be educated to absorb more oxygen. The presence of a large amount of carbon dioxide in the tissues facilitates dissociation. The carbon dioxide which is given off by the tissues is likewise taken up by the blood and is transported back to the lungs and given off to the alveoli. Normal atmospheric air contains about 0.04 per cent of carbon dioxide, normal alveolar air 4.5 per cent. When an individual exercises he produces more carbon dioxide, the fraction shows an excess in the numerator and the individual breathes more rapidly in order to eliminate or wash out the excess carbon dioxide and restore equilibrium in the fraction. If he breathes forcibly at rest he washes out carbon dioxide, develops apnea and stops breathing, or breathes more slowly until he reaccumulates enough carbon dioxide to restore equilibrium in the fraction. The respiratory center in the brain stem which controls breathing is affected by a respiratory hormone which is the H-ion concentration and slight changes in this concentration cause stimulation or lack of stimulation of the respiratory center as the case may be. Under conditions requiring more oxygen the subject may breathe more deeply, thus exposing a greater area of the lung capillaries to the alveolar air. In conditions in which more oxygen is needed or where there is accumulation of carbon dioxide, the breathing increases in rate and depth, thus facilitating respiratory exchange over a greater area between the lung capillaries and the alveoli. The heart rate may increase, thus exposing the blood more often in a given length of time to the alveolar air. We have, then, a close interrelation between the respiratory and circulatory systems.

To summarize, we have, under normal conditions, a respiratory exchange whereby oxygen is absorbed from the alveoli of the lungs into the blood and carbon dioxide given off from the blood to the alveoli. This respiratory exchange is made possible in part by our breathing air of sea level composition at a certain rate and depth. The blood, by means of its hemoglobin in the red cells and its plasma, carries oxygen to the tissues and under proper chemical conditions gives off the oxygen needed by the tissues, takes up carbon dioxide given off by the tissues and returns it to the lungs. A disturbance of any one of these factors causes an upset in normal functioning of the circulatory and respiratory systems. As we shall see, all of these factors are disturbed by the condition of oxygen want.

We must, therefore, consider what the effects of high altitudes are, and how the body adapts itself to meet these changed conditions.

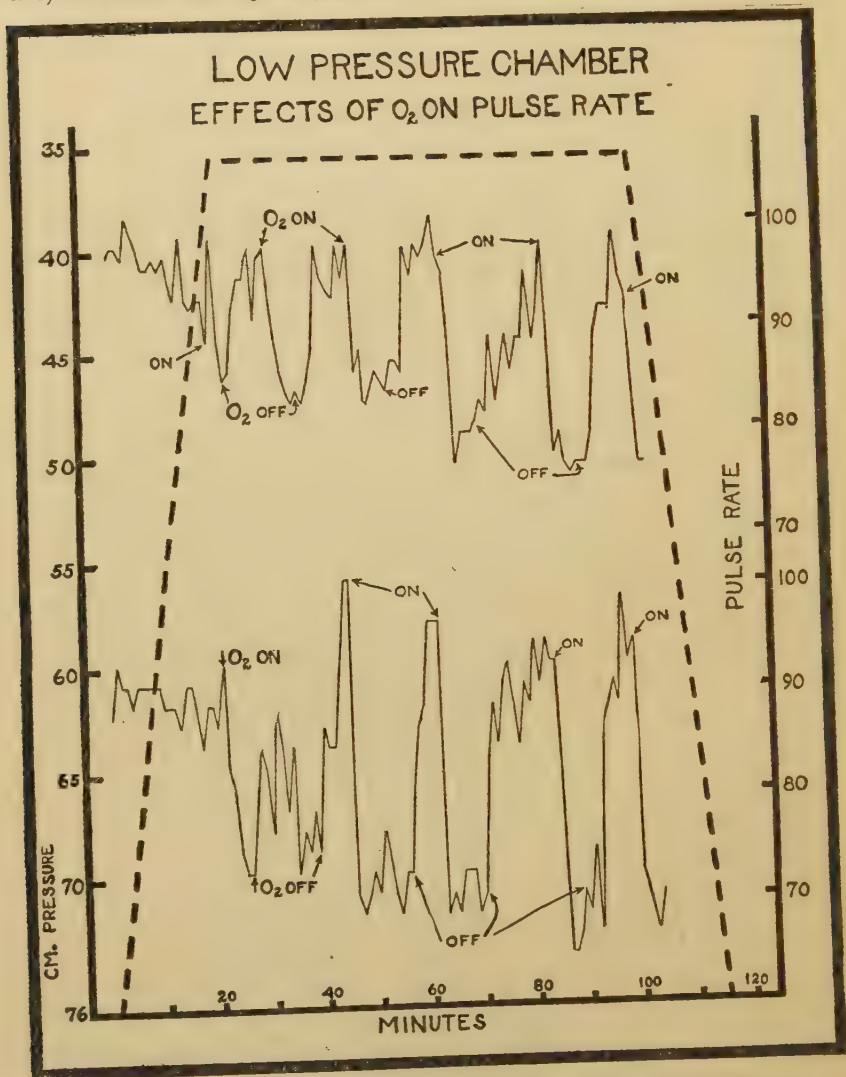


FIG. 16. CHART PROVING THAT THE REDUCED PARTIAL PRESSURE OF OXYGEN IS THE IMPORTANT FACTOR IN ALTITUDE

When the subject was given pure oxygen to breathe, his pulse rate immediately fell even though the barometric pressure remained the same. When the oxygen was taken away his pulse rate immediately accelerated (Schneider).

There are numerous physical factors in the atmosphere that are changed as we ascend from sea level to a higher altitude. The ones which are most important for us to consider are the following, diminished atmospheric pressure, diminished partial pressure of oxygen, lowered temperature and humidity. The most important one from the standpoint of aviation is the second or diminished partial pressure of oxygen. That this is the case was first shown by Paul Bert (3) as far back as 1878. His results were later disputed but have since been corroborated. The proof of this is easily shown by the administration of oxygen to a person suffering from oxygen want at simulated high altitudes, such as are obtained in a low pressure chamber. Were barometric pressure the cause of the symptoms, the administration of oxygen could have no effect. Were the percentage of oxygen important, except in so far as it affects the partial pressure of oxygen, altitude would not cause inefficiency, for the percentage of oxygen remains the same at any altitude. Lutz and Schneider (11) showed that the pulse rate of an individual at 18,000 feet was considerably above normal, that upon the administration of oxygen the pulse rate immediately fell to normal, upon withdrawal of oxygen the pulse rate immediately went up, and again upon administering oxygen the pulse rate fell. This was carried out in a number of cases and is conclusive proof that diminished partial pressure of oxygen is the important factor in altitude. The factors of cold and lowered humidity will be considered later on, but for the present we may say that they are purely secondary conditions. At sea level we have 760 mm. Hg barometric pressure and 20.96 per cent oxygen, giving us a partial pressure of oxygen of about 159 mm. Hg. At 10,000 feet we have 516 mm. Hg barometric pressure and 20.96 per cent oxygen, or about 108 mm. Hg partial pressure of oxygen. At 20,000 feet a barometric pressure of 354 mm. Hg and 20.96 per cent oxygen, giving a partial pressure of oxygen of about 74 mm. Hg. In other words, as we ascend, the percentage of oxygen remains constant, the barometric pressure falls, and, what is important, the partial pressure of oxygen decreases. This reduction in the partial pressure of oxygen causes imperfect saturation of the blood with oxygen. As a result the tissues are imperfectly supplied with oxygen thus affecting certain bodily functions. This imperfect saturation of the tissues with oxygen is called anoxemia. There are three types of anoxemia but the one with which we are concerned is the anoxic type which is caused by a lack of availability of sufficient oxygen.

That the effects of high altitude have striking results upon the efficiency of the aviator will be seen from the following quotations of experiences at high altitudes (1).

The action of gradually developing oxygen want, at very high altitudes is very insidious as dangerous effects may develop with a dramatic suddenness. Two now historic experiences illustrate this. In 1862 the well known meteorologist, Glaisher, and his assistant, Coxwell, ascended in a balloon. Glaisher first noticed at an altitude of about 26,000 feet that he could not read his instrument properly. Shortly after this his legs were paralyzed and then his arms, though he could still move his head. Then his sight failed entirely and afterwards his hearing and he became unconscious. His companion meanwhile found that his arms were paralyzed, but that he was still able to seize and pull the rope of a valve with his teeth this permitted gas to escape—so that the balloon descended. As Glaisher recovered consciousness, he first heard his companion's voice and then was able to see him, after which he quickly recovered. The balloon, during the ascent, reached an altitude of about 30,000 feet.

The second of these historic experiences is found in a graphic account given by Tissandier, the sole survivor of a party of three in a fatal balloon ascent in 1875.

I now come to the fateful moments when we were overcome by the terrible action of reduced pressure. At 22,900 feet (320 mm.) we were all below in the car—torpor had seized me. My hands were cold and I wished to put on my fur gloves; but, without my being aware of it, the action of taking them from my pocket required an effort which I was unable to make. At this height I wrote, nevertheless, in my notebook almost mechanically and reproduce literally the following words though I have no very clear recollection of writing them. They are written very illegibly by a hand rendered very shaky by the cold: "My hands are frozen. I am well. We are well. Haze on the horizon, with small round cirrus. We are rising. Croce is panting. We breathe oxygen. Sivel shuts his eyes. Croce also shuts his eyes. I empty aspirator, 1:20 p.m., -7 to -11 degrees, barometer 320. Sivel is dozing, 1:25, -11 degrees, barometer 300. Sivel throws ballast (last word scarcely legible)" I had taken care to keep absolutely still without suspecting that I had already perhaps lost the use of my limbs. At 24,000 feet the condition of torpor which overcomes one is extraordinary. Body and mind become feebler little by little, gradually and insensibly. There is no suffering. On the contrary one feels an inward joy. There is no thought of the dangerous position; one rises and is glad to be rising. The vertigo of high altitude is not an empty word; but so far as I can judge from my own impressions this vertigo appears at the last moment, and immediately precedes extinction, sudden, unexpected, and irresistible. I soon felt myself so weak that I

could not even turn my head to look at my companions. I wished to take hold of the oxygen tube but found that I could not move my arms. My mind was still clear, however, and I watched my aneroid with my eyes fixed on the needles which soon pointed to 290 mm. and then to 280. I wished to call that we are now at 26,000 feet, but my tongue was paralyzed. All at once I shut my eyes and fell down powerless and lost all further memory. It was about 1:30.

The balloon ascended 28,820 feet and then descended. Tissandier recovered but his companions lost their lives in the ascent. These extreme cases are cited here in order to bring to the reader's attention the risk in going to extremely high altitudes without oxygen.

Statement of an American Officer relative to an altitude flight in 1918.

In order to take an aeroplane to a higher altitude than any other pilot in the world, I found that it would require more than one or two attempts. I made three attempts. The first one took me to 24,000 feet, the second to 27,000 feet, and the last one to 28,900 feet but now I feel certain that I can get to at least 30,000 feet.

I took off at 1:45 p.m. Wednesday, September 18, 1918, and made a steady circular climb, passing through clouds at 8000 feet, 12,000 feet, and 16,000 feet. At 20,000 feet, while still climbing in large circles, my goggles became frosted, making it very difficult for me to watch my instruments. When I reached 25,000 feet I noticed the sun growing very dim, I could hardly hear my motor run, and I felt very hungry. The trend of my thoughts was that it must be getting late, that evening must be coming on; but I was still climbing, so thought I might as well stick to it a little longer, for I knew I could reach my ceiling pretty soon, then I should go down, and even though it were dark I could land all right, for I had made night landings many times before, and so I went on talking to myself, and this I felt was a good sign to begin taking oxygen, and I did. I was then over 25,000 feet, and as soon as I started to inhale the oxygen the sun grew bright again, my motor began to exhaust so loud that it seemed something must be wrong with it. I was no longer hungry and the day seemed to be a most beautiful one. I felt like singing with sheer joy as I gazed about through a small portion of my goggles which had no frost, due to a drop of oil which had splashed on them from the motor.

It was wonderful to see the very clear blue sky with the clouds thousands of feet below. The frost on my goggles bothered me very much. At times I had to remove my gloves in order to put the warm palm of my hand on the glass to thaw the frost. I did this about every ten minutes, so that I could take the proper readings of the instruments, which I marked down on my data pad. I believe that if my goggles had been better ventilated they would not have frosted. When I was about 27,000 feet I had to remove my goggles, as I was unable to keep a steady climb. My hands by this time were numb, and worried me considerably. The cold raw air made my eyes water, and I was compelled to fly with my head well down inside the cockpit.

I kept at it until my oxygen gave out, and at that point I noticed my aneroid indicated very nearly 29,000 feet. The thermometer showed 32° below zero C. and the R.P.M. had dropped from 1600 to 1560. This is considered very good. But the lack of oxygen was affecting me, I was beginning to get cross, and I could not understand why I was only 29,000 feet after climbing for so long a time. I remember that the horizon seemed to be very much out of place, but I felt that I was flying correctly and that I was right and the horizon wrong.

About this time the motor quit. I was out of gasoline, so I descended in a large spiral. When I had descended to about 20,000 feet I began to feel much better and realized that the lack of oxygen had affected me. I passed down through the clouds at 16,000 feet, and as I remember it was snowing from these clouds upon the next layer some 4000 feet below. I am not positive of this, as I may have been affected by the lack of oxygen. I noticed as I descended that the air seemed to be very thick and stuffy, but very nice and warm. I did not see the ground from the time I went up through the clouds above Dayton, Ohio, until I came down through them again at 4000 feet above Canton, Ohio, over 200 miles from where I started.

I was lost beyond a doubt, with a dead engine over very rough country. I landed O.K., and broke the tip of my propeller, which was standing vertical, when I rolled into a depression in the ground. However, I did not nose over or do any other damage to the plane or myself. I flew back to Dayton with a new propeller.

My lips and four of my fingers were frozen and required medical attention. Electrically heated clothing would have been very well used, but I dressed as light as possible to avoid the extra weight, as I had stripped the entire plane of all unnecessary load. This was done to assist in climbing.

It will be noted that the effects of high altitude on these individuals came on insidiously. The men, thus, were not cognizant of the serious condition in which they were. An aviator not only does not appreciate that he is suffering from oxygen want but is firmly convinced of the contrary. Note that the American officer in the third quotation said that he was firmly convinced that he was right and the horizon wrong. This is no unusual attitude by any means. Those of us who have seen many tests on the rebreather have noted time and again that the subject may become absolutely inefficient and utterly neglect his tasks and yet insist when restored to fresh air that he was doing everything perfectly and that there was no necessity for taking him off. We will now consider the effects of altitude on the respiratory and circulatory systems in more detail.

RESPIRATION

The first factor we shall consider is that of respiration. The respiration affords the first, and perhaps the most important com-

pensation to the diminished partial pressure of oxygen as found at high altitudes. As the amount of oxygen decreases, the subject endeavors to make up for this by increasing the depth of respiration, thus bringing more oxygen, or rather oxygen over a greater surface, in contact with the lung capillaries. Oxygen want causes increased

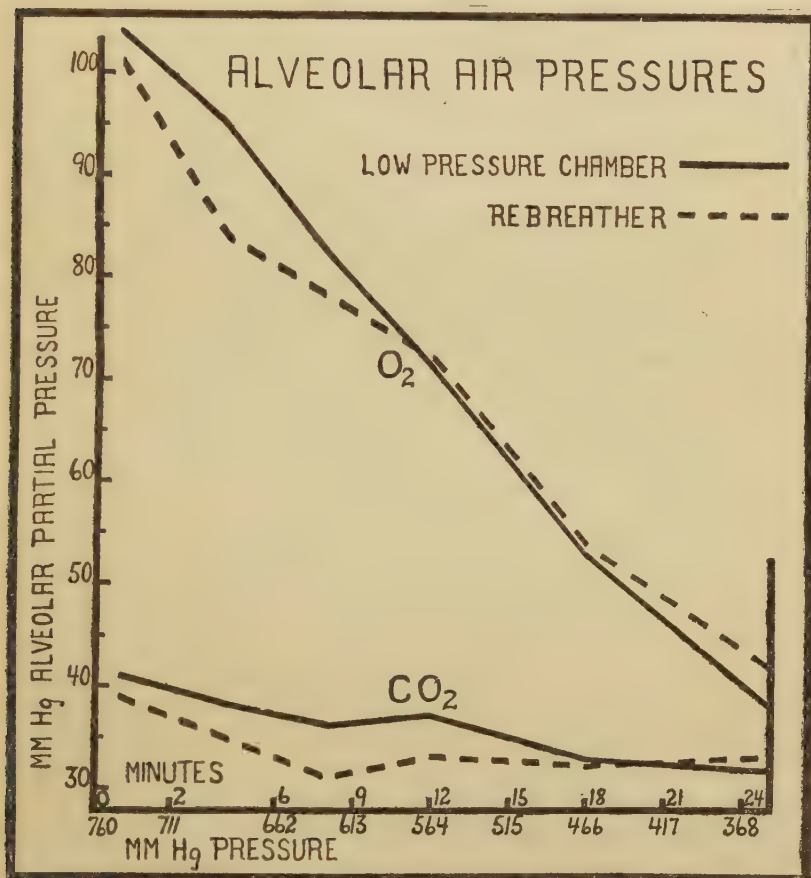


FIG. 17. FROM THE AIR SERVICE MEDICAL

depth of respiration and this in turn washes out a large part of the carbon dioxide from the alveoli and eventually from the blood. The normal stimulus for respiration would then be gone were it not for the fact that oxygen want itself acts as a stimulus. Under normal conditions the alveolar oxygen pressure is considerably lower than the

oxygen pressure in the atmosphere. Remembering, then, that we have approximately 100 mm. partial pressure of oxygen in the alveolar air, under normal conditions, we will find that with the increase in lung ventilation which results from altitude, we have a fall in alveolar oxygen pressure from the normal of 100 mm. to approximately 35 mm. at 20,000 feet. The normal carbon dioxide pressure at sea level is approximately 40 mm. The washing out of carbon dioxide due to increased ventilation causes a fall from 40 mm. at sea level to about 30 mm. at 20,000 feet. Lutz and Schneider (9) show that changes in the alveolar carbon dioxide pressure occur as low as 4000 feet. Schneider (12) reports in the Air Service Medical that aviators sometimes develop a Cheyne Stokes breathing that can be abolished by the administration of oxygen. There is also a decrease in the vital capacity with lowered barometric pressure but the cause is in dispute. We saw that the average individual breathes about eight liters per minute. Under the changed conditions which are outlined above, the aviator compensates by breathing a much greater volume of air per minute. In a good type of reactor there is an increase of anywhere from three to ten liters per minute. This results in opening all the lung alveoli and bringing oxygen in contact with a much greater surface of lung capillaries than is the case at sea level. As a result the actual oxygen pressure is raised above that which we would expect at the altitude in question.

The aviator is usually conscious of the fact that he needs to breathe more deeply when he reaches altitudes above 15,000 feet. He will tell you that he breathes with open mouth, more deeply and occasionally more rapidly. On return to sea level, he will breathe sub-normally. His excessive breathing has resulted in washing out carbon dioxide; oxygen want is no longer present, there is therefore no stimulus acting on the respiratory center and he breathes sub-normally until he reaccumulates enough carbon dioxide to reestablish the chemical equilibrium of the blood.

THE HEMATORESPIRATORY FUNCTION OF THE BLOOD

The washing out of carbon dioxide by deep breathing produces an alkalosis in the blood, in other words the numerator of our fraction, $\frac{\text{H}_2\text{CO}_3}{\text{NaHCO}_3}$, has become reduced. We have a condition, then, in which there is a deficient supply of oxygen, resulting at very high altitudes in the blood getting insufficient oxygen from the lungs.

Likewise there is washing out of carbon dioxide producing an alkalosis which results in a condition unfavorable to dissociation of oxygen from the hemoglobin when the blood reaches the tissues.

The next factor to be considered is the effect on the circulatory system.

PULSE

The pulse rate shows an increase under the effects of altitude. The heart rate has been shown by Lutz and Schneider (10) and by Schneider and Truesdell (16) to be slowly and gradually increased to 14,000 feet and from there on a greater increase occurs. If a level is maintained for an hour or two, according to Schneider and Lutz (10), the rate tends to return to that of sea level. When the subject returns to sea level or is given oxygen, the rate returns at once to the normal. The amount of increase depends upon the rate, height and duration of ascent and the physical condition of the subject. The increase in pulse rate, by passing blood more rapidly through the lungs, thus exposing a greater volume of blood to the air in the alveoli in a given time, was considered as a compensation. The idea was that pulse rate was an indication of increased blood flow. Experimental work on blood flow by Barcroft (2) and by Schneider and Truesdell (16) have shown that blood flow is not increased. Therefore the increased pulse rate does no good and must therefore be considered as a sign of distress. In an individual who reacts poorly to low oxygen we sometimes get a sudden fall or break in the pulse and fainting ensues.

BLOOD PRESSURE

Blood pressure may or may not show a change. In a good compensation there will be very little change in either systolic or diastolic pressure until moderately high altitudes are reached, when there will be a rise in systolic and a controlled fall in diastolic giving an increase in pulse pressure. In individuals who have a systolic blood pressure of 140 or over at sea level there may be considerable increase in systolic pressure under the influence of low oxygen, but Schneider and Truesdell (17) found no difference in the response of men with a high or low systolic pressure. In the so-called rebreather examinations, Schneider and Truesdell (17) showed that the systolic pressure maintains a level or shows a slight terminal rise of 10 to 15 mm., in cases of good compensation. The diastolic remains on a level until 15,000 feet is reached and then there is a gradual fall of 8 to 10 mm.

In cases of poor compensation the systolic and diastolic pressure may break and fainting occur. The increased pulse pressure, taken in conjunction with increased pulse rate was considered to be a form of compensation. Inasmuch as the two are not considered reliable indications of blood flow, increased pulse pressure must also be considered a sign of distress. Schneider (13) found in a series of experiments in the low pressure chamber and on the rebreather, that venous pressure was reduced by altitude. Schneider and Truesdell (16) report that capillary pressure, so far as they have been able to determine is not influenced by oxygen want. There were some variations but these variations were in both directions. In some cases there seemed to be a slowing of the flow and a granularity followed by clumping of the red cells. In other cases the flow remained regular and homogeneous throughout the experiment. What changes occurred in pressure or in rate of flow were restored to normal on restoration of the subject to fresh air.

BLOOD FLOW

The question about blood flow is still somewhat undecided. The early experiments which took the product of pulse rate and pulse pressure as indicating blood flow led us to believe that there was increased blood flow. Recent experiments have indicated that pulse rate $\times$ pulse pressure is not an indication of blood flow. In experiments by Barcroft (2) and Schneider and Truesdell (16) it is indicated that there is actually a decrease in blood flow rather than an increase. Increase in pulse rate and pulse pressure are interpreted as signs of distress rather than as compensations.

BLOOD CHANGES

It has long been known that residents at high altitudes have a greater number of red cells and hemoglobin than residents of lower altitudes. The Anglo-American Pike's Peak (5) expedition found that there was an increase in red blood corpuscles and hemoglobin in equal proportion. We, however, are interested in the aviator. Various observers have reported increases in red cells and hemoglobin during flights to high altitudes, some of them giving cold as a cause. Most of them, however, have failed to take into consideration the fact that there is a diurnal variation in hemoglobin, varying anywhere from 10 to 30 per cent according to Dreyer, Bazett, and Pierce (6).

The time required for altitude blood changes to occur, according to Schneider (14), depends upon the rate and height of ascent, the physical condition of the subject and to a certain extent by the amount of physical effort. Gregg, Lutz and Schneider (7), in a series of experiments in the low pressure chamber and rebreather found that when simulated ascents were made to 15,000 and 18,000 feet at the rate of 1000 feet a minute, both red blood cells and hemoglobin increased in 78 per cent of the cases. In the majority of cases the increase began between forty and sixty minutes and in some as early as twenty-six minutes after ascent. As to how this increase in hemoglobin and red cells can be brought about in so short a time is in dispute. While an increased hematopoietic activity of the bone marrow unquestionably accounts for the increase in the acclimatized individual, it obviously cannot account for the increase in the aviator as the time is too short. There may be an unequal distribution of red cells but there seems to be no experimental evidence to prove this. That there may be a reserve supply of red cells was first pointed out by Schneider and Havens (15). More recent studies by Broun (4) lend considerable weight to this possibility. In connection with a series of experiments on dogs, Broun says, "It will be noted that ten to fifteen minutes of active exercise caused usually a slight increase in plasma volume and quite regularly a marked increase in cell volume hemoglobin, pigment volume and number of corpuscles per cubic millimeter." Another explanation is that it is due to increased concentration of the blood. How this concentration occurs, whether by absorption of water into the muscles, into serous cavities, through the kidneys or the skin, is a matter on which there is considerable conflicting testimony. Whichever happens—in fact both may occur—the result is, the pulse rate tends to return toward normal after an hour at high altitude. As this fall coincides with the increase in hemoglobin and red cells, the latter increase probably accounts for it.

COMPARISON WITH THE MOUNTAINEER

In order that we may appreciate a little better the nature of the adaptive changes occurring in the aviator, we may briefly consider those in the mountaineer. The changes in the aviator are the same as those occurring in the mountaineer except that they have not gone so far. The aviator never becomes acclimatized because he does not remain at high altitude a sufficient length of time. In the

mountaineer breathing continues to increase for some days, and maintains a high level, and the explanation for this is, that, originally, oxygen want serving as a stimulus to the respiratory center caused increased breathing, carbon dioxide is then washed out, causing alkalosis. The kidneys and the liver then attempt to effect an equilibrium in the chemical equation, the kidneys by excreting alkali and the liver by suppressing the accumulation of free ammonia. The alkalosis is thus at least partially redressed. The H-ion concentration tends to return to a normal proportion by a reduction of both sides of the fraction. The breathing remains high, however, and whether this is due to a continued slight alkalosis as claimed by Haldane (8) or to an acidosis as claimed by Barcroft (2) is a matter not definitely settled. Pulse rate likewise tends to fall after some days, when the bone marrow takes on increased activity and supplies additional red cells necessary for the increased consumptions of oxygen.

In the aviator the alkalosis develops as in the mountaineer, but the kidneys and liver do not have the opportunity to restore the balance so that his alkalosis continues until he returns to sea level where he restores the balance by decreasing his breathing as already explained. His bone marrow has not opportunity to take on increased activity, so that only less marked and temporary relief can be given by a concentration of the blood producing a relative increase in the red cells and hemoglobin, or by using reserve cells.

LIMIT OF HIGH ALTITUDE

While in general it may be said that the administration of oxygen abolishes the symptoms of anoxemia, there is a limit to which man can go even with oxygen. The aviator should be restricted in his work to the level at which he is most efficient. How this can be done will be shown when we speak of altitude classification tests. Whatever his ability, no man should fly above 18,000 to 20,000 feet without oxygen. In fact, it has been found, that repeated long flights to 15,000 feet or more result in less fatigue if oxygen is taken. The British were the first to call attention to this. The increased percentage of oxygen breathed results in an increased pressure of oxygen in the alveoli.

The average limit at which man becomes unconscious without oxygen is in the vicinity of 25,000 feet. This level, however, varies with individual factors and also with the speed with which the

altitude is gained. Now as to the limit to which man may go with oxygen. The general impression, especially among aviators, is that there is no limit so long as oxygen is taken. That there is a limit and a very definite limit will be shown.

The life of man is dependent not on the quantity or percentage of oxygen in the atmosphere but upon its pressure. Somewhere between 40,000 and 45,000 feet is undoubtedly the absolute limit for man even when supplied with oxygen under the ordinary circumstances. Somewhere between these limits, the exact point depending upon the temperature of the air, the barometric pressure is reduced to 100 mm. of mercury. From this atmospheric pressure must be deducted 47 mm. of water vapor, which accumulates in the inspired air before it reaches the lungs. This leaves 53 mm. possible available oxygen pressure if pure oxygen is breathed. Now if man breathed absolutely pure oxygen this would be sufficient to sustain life, but under no present available method of taking oxygen, either through a tube or through a mask, does the oxygen remain undiluted. It does become diluted and therefore decreased to a great extent by the nitrogen of the air. Likewise under the effects of the diminishing pressure nitrogen is given off by the blood as in caisson disease, still further diluting the alveolar air. Therefore, this 53 mm. of pressure does not represent the true available oxygen pressure in the depths of the lungs but it is less than that. Forty millimeters available oxygen pressure in the depths of the lungs is about the minimum. Even at this point the blood is somewhat venous and the individual is suffering from extreme oxygen want. However, if the available oxygen pressure can be kept at about that point, it is possible for the individual to continue under these conditions so far as oxygen is concerned, if the carbon dioxide pressure is kept up. This oxygen want, however, causes the carbon dioxide to be lost from the body with a rapid fall in the carbon dioxide pressure. This results in decreasing the dissociation of the oxygen from the hemoglobin in the tissues, so that if the carbon dioxide pressure falls below 40 mm., even though the oxygen pressure remains at that point, the individual will not receive sufficient oxygen in the tissues to continue life. He might go a little higher if he should receive a mixture of carbon dioxide and oxygen. It cannot be too strongly impressed that beyond this critical line, between 40,000 and 45,000 feet it is absolutely impossible for a human being to go and live even though he is breathing pure oxygen, for beyond this point the available oxygen pressure

in the lungs will be too low to sustain life. There is one exception to the above statement. The individual could go beyond this point provided he were inclosed in a cabinet or suit in which the barometric pressure were kept at a point compatible with life. There are two possible solutions to this problem. One is by the construction of a pneumatic suit, on the principle of, but different from that used in caisson work. This suit would be filled constantly with oxygen and would have a CO₂ absorber in it so that the individual would not accumulate too much carbon dioxide, for this would be as dangerous as the loss of carbon dioxide. Even with a pneumatic suit, however, it is not seen how it is possible to prevent that suit from expanding outside, due to the decreased external barometric pressure which would result in a corresponding expansion of the oxygen in the suit and probably a reduction of its pressure beyond the critical point. In the other method, the aviator would be enclosed in a pneumatic cabinet in which the pressure would be kept up artificially to a point compatible with life. These are theories for future solution, but for the present, man must be kept below a definite critical level.

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CHAPTER VII

EFFECTS OF ALTITUDE ON THE HEART

It has always been assumed that altitude has a bad effect on the heart and cardiac patients have always been advised to keep away from high altitudes. There is very little scientific knowledge on which to base this. It was noted that a number of cases of fainting and collapse occurred at high altitudes and at simulated high altitudes, such as in the low pressure chamber and on the rebreather.

Whitney (5) as a result of investigations concluded that there is heart failure following marked cardiac dilatation, sometimes as great as from 3 to 5 cm. He noted that dilatation was apparent by percussion before symptoms occurred. He claimed that not only was it necessary to maintain efficiency of the circulation, but that the heart itself was vulnerable to the effects of oxygen deficiency. If the circulation falters, the nerve centers may be paralyzed by anoxemia and nutrition of the heart muscle is impaired. Further interference with circulatory efficiency follows and collapse is inevitable. The collapse coming without any warning, he explains sudden fainting at high altitudes as being due to this sequence of events. He found that the type most apt to show dilatation was an emotionally high strung man or a man who was out of condition. Men with defective hearts or blood vessels simply become inefficient instead of making the strain. He believes a test of low oxygen is an excellent cardiac test and that slight cardiac lesions may be demonstrable in such a test which are not apparent by other means. There is no question but that we have a type of circulatory collapse, the subject turns pale, is in a cold perspiration, there is loss of muscular tone, sometimes muscular twitching and collapse of vaso-motor tone evidenced by falling blood pressure and pulse. Fainting follows if oxygen is not given promptly. Whether or not this fainting due to circulatory failure is accompanied by cardiac dilatation is another question.

The x-ray has taught us how faulty is the information we obtain by percussion. In order to settle whether or not cardiac dilatation

did occur at high altitude, LeWald and Turrell (4) undertook a series of experiments in which roentgen photographs were taken of the heart at every thousand feet of simulated altitude. Some of these experiments were carried out on the rebreather and some in the low pressure chamber. Plates were taken in the same phase of respiration so far as possible and arrangement was made whereby exposure was started by the pulse wave so that the photograph would be always in the same phase of the cardiac cycle. The transverse diameter of the heart was then measured and likewise the area of the heart computed by means of a planimeter and the results compared. Control photographs were also taken before and after the experiments. They found that pictures taken during forced inspiration and at forced expiration without the subject being under the effects of low oxygen at all differed markedly in the transverse diameter of the heart. Whitney found by percussion that dilatation of the heart occurred chiefly toward the left but also in some cases to the right as well. LeWald and Turrell found that differences in transverse diameter of the heart in forced expiration and inspiration amounted in many cases to over 3 cm. During normal respiration, changes in transverse diameter are comparatively small. In the low oxygen tests they found that in 66 cases there was no cardiac enlargement at any time during the test, that there was slight increase in 9, 7 of which were explicable by the fact that the plates were not all taken in the same respiratory phase. Eleven cases showed actual decrease in the transverse diameter. In these 11 cases, 6 may be explained by different respiratory phases in which the photographs were taken. Five, all of whom showed evidences of circulatory failure, gave a definite decrease in the transverse diameter and cardiac area. The explanation of this may possibly be that when collapse occurred the amount of blood in the heart was less, most of it being in the splanchnic area. Inasmuch as we know that the subject is breathing forcibly when under the effects of low oxygen it was suggested by LeWald and Turrell that Whitney and his associates, in percussing the area of the heart at high altitudes, found the left border during forced expiration and did not note that the border came down on inspiration.

This work of LeWald and Turrell seems to settle rather definitely that cardiac dilatation does not occur when collapse occurs at high altitudes. Etienne and Lamy (1) claim to have noted a cardiac hypertrophy in aviators after moderate flying. In the United States

Air Service we have not noted any such enlargement. We have noted, however, a number of different types of hearts and we are inclined to look with skepticism on the claims that aviation causes cardiac hypertrophy.

Further work has been done in respect to the heart on the electrocardiograph by Greene and Gilbert (2). Subjects were placed on the rebreather and electrocardiograms taken at intervals throughout the test, a continuous electrocardiogram being taken just before completion of the test lasting until the subject was completely recovered. They found that the general changes in the heart on the electrocardiograph were slight until the critical stage was reached between inefficiency and complete unconsciousness. Precrisis changes showed shortening of the time of the P-R interval, decrease in the total time of the R-T interval and a decrease in the amplitude of the T wave. Postcrisis changes are slowing of the rate, displacement of the pacemaker and interference with normal conduction leading to dissociation. The postcrisis rate drops sometimes five or more per minute and is associated with the development of auriculo-ventricular rhythm. Sino-auricular rhythm was slowed and disappeared altogether followed by the establishment of an auriculo-ventricular rhythm, in 3 cases carried to extreme.

Gilbert and Greene (3) also reported a sphygmographic study of the pulse under the effects of low oxygen. Sinus arrhythmia, as a rule, showed an increase in the early part of the test and as the pulse accelerated it decreased and frequently disappeared. Premature ventricular contractions were found to increase in frequency during low oxygen tests and then, as pulse accelerated, their incidence decreased and they finally disappeared. At the School of Aviation Medicine we have occasionally found cases in which premature beats were frequent before the test, continuing to increase in frequency to such an extent as to be alarming, causing the subject to be removed from the test. In general, however, we may say that the effect of low oxygen on premature beats is the same as that of exercise.

Finally, it may be said that altitude affects the circulatory system as a whole, chiefly because of the development of vaso-motor inefficiency and that the heart is not under greater strain than the rest of the circulatory system. In a subject with no organic defect and with soft arteries, the effects of altitude make no lasting

impression on the heart or circulatory system. Recovery is prompt on the administration of oxygen and there are no lasting after affects.

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CHAPTER VIII

PSYCHOLOGICAL EFFECTS OF ALTITUDE

We have discussed in a previous chapter the physiological effects of altitude and we will now take up the question of the psychological effects. Dunlap and his associates were the first to work out the results of low oxygen tension on the nervous system. They found that the primary and important psychological effects of oxygen want are on attention and voluntary coördination. When the subject reaches the stage in which he is rapidly approaching unconsciousness other effects are noted. Until that stage, however, no effects are noted which are not due either to failure of voluntary attention, motor coördination or both. Perception remains efficient but the power to attend to stimuli diminishes. Discrimination and judgment show no falling off except as a result of the impairment of these two factors. Memory is apparently not affected, except as inability to attend to details or inability to control expression may enter in. Watson (5) and Dunlap (2) quote incidents of tests used to bring out these facts. In testing perception and discrimination the test consists in copying of lists of words and the translation of words into code. In both cases they found that speed and accuracy were maintained up to the final stage of anoxemia provided accommodation and convergence were not markedly affected. He (Watson) found, however, that the mechanism for handwriting was so affected that writing could be read only with difficulty. In more complicated discrimination tests where rapid and accurate recognition and classification of material are required, the results were similar. He states also that sensitivity and acuity of sense organs show no consistent impairment. He gives the distinctive effect on the nervous system as a change in its integrative action and not as a change in any particular part or unit. He suggests the picture of anoxemia as comparable to that of progressive alcoholic intoxication. Allowed a moment without a task, the subject may pull himself together for a brief space of time causing what is known as "attention peaks." Dunlap (3) in another article expresses much the same thing by stating that the effects of altitude

are on the integration of the nervous system, evidenced in decreased sensori-motor coördination and in range and sustention of attention. The higher mental processes are affected in so far as they depend on attention and coördination. Attention peaks result.

Bagby (1) finds that a number of unusual symptoms may develop during the final stages of oxygen want from a psychological point of view. He offers an explanation for them in a discussion of behavioristic psychology under low oxygen. He states that milder traits of the "nervous" aviator can be elicited by a number of situations. In the examination, questions as to feelings of fear will usually be responded to in the negative but yet a situation may be devised that will arouse a sufficient reaction of fear. The rebreathing test appears to the flyer as a dangerous situation and consequently it is a good stimulus for fear of the abnormal sort. Abnormal fear reactions under such a condition may be shown by a forced air of ease, uneasiness, inattention and various physiological disturbances such as increased pulse, increased respiration and even fainting. Failing any such response, the "nervous" aviator may still reveal abnormality by hysterical reactions. This may be shown by pretended fainting or by removal of inhibitions during the final stages of the test, the reactor becoming sullen, angry, destructive or silly. When these tendencies occur at moderate altitudes they are significant. He claims that to a certain extent it is possible to gauge the general attitude of the aviator by the way he handles the psychological features of the test. He believes the individual best suited for pursuit work is restless and unconcerned, while one best suited for piloting an observer is accurate, precise, only moderately rapid, painstaking and careful.

In a discussion of the personality of the aviator under low oxygen tension, Paton (4) states that he found increased irritability of the kneejerk, as a rule, although sometimes there is a decreased irritability, which he attributes to apparent hypertension and inability to relax. He noted indication of oxygen want in the facial expression which showed varying degrees of anxiety, indefinite states of apprehension, and slight incoördination of the finer movements.

Finally, the following general statements about altitude may be added together with a summary of the effects of altitude in the nervous system.

The effects of altitude on the aviator come upon him unawares. The most striking effect is on the nervous system and results first in

stimulation and a feeling of well being. This is quickly followed by a decrease in the field of attention, by an increased distractibility, and by a loss of control of voluntary muscles. At very high altitudes memory, judgment, hearing and vision are impaired first as a result of the effects on attention and motor coördination and finally directly, just before unconsciousness supervenes. Sleepiness is common and fainting may ensue. Between 23,000 and 25,000 feet is the upper limit of consciousness for man without oxygen. There may be certain abnormal reactions to low oxygen such as euphoria, (continued beyond the initial stage as noted above), anger, destructiveness, fear, and silly laughter.

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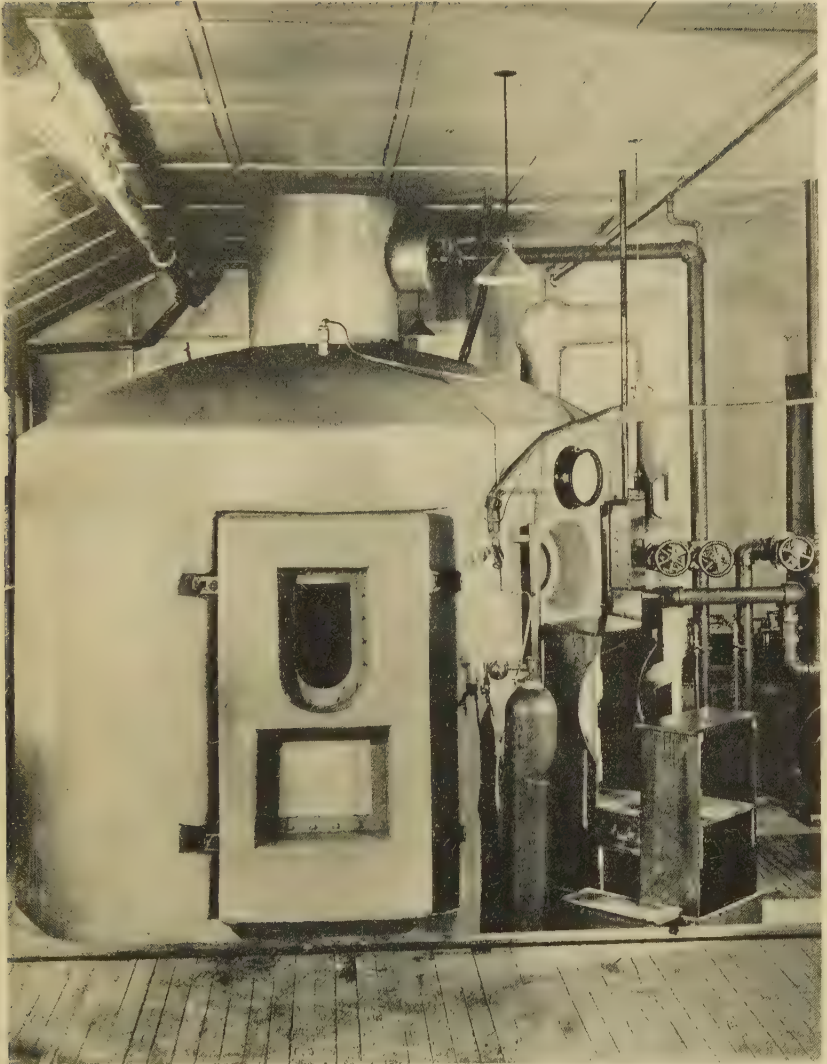


FIG. 18. THE LOW PRESSURE CHAMBER AT THE SCHOOL OF AVIATION MEDICINE

CHAPTER IX

AN ALTITUDE CLASSIFICATION TEST

We have seen that the effects of altitude are insidious. The subject may become absolutely inefficient and not realize it. He cannot judge of his limitations, his inhibitions are relaxed and his judgment is dulled and he may become unconscious without realizing that he is reaching the danger zone. We must, therefore, have a test to determine the ability of the individual to compensate for oxygen want. What method shall we adopt? First of all we have the low pressure chamber. This is a steel chamber controlled by a vacuum pump which forces a constant stream of fresh air through the chamber. In simulating ascent the air is pumped out faster than it is allowed to enter and in simulating descent the air is permitted to enter faster than it is pumped out. Any altitude may be maintained as long as desired. This is a complicated and expensive piece of equipment and necessitates a prolonged test. We may use a nitrogen dilution apparatus such as that devised by Dreyer. In this, the subject breathes a stream of air in which there is a steadily increasing percentage of nitrogen. The barometric pressure remains the same but the oxygen pressure is reduced by increased percentage of nitrogen. Criticisms of this apparatus are, that it easily gets out of adjustment and that, in this country, it is difficult to obtain absolutely pure nitrogen. The third method involves the use of a rebreathing machine such as that devised by Henderson and Pierce (1) or by Larsen (3). In this apparatus the subject breathes over and over again the same air with the carbon dioxide removed. He burns up the oxygen, thus constantly reducing its percentage. All three of these methods result in reducing the partial pressure of oxygen. The low pressure chamber does it by reducing the barometric pressure, keeping the percentage of oxygen constant; the Dreyer apparatus does it by keeping the barometric pressure normal and reducing the percentage of oxygen by diluting it with nitrogen; and the rebreather does it by the same method as the Dreyer apparatus but by reducing the oxygen percentage in another manner. We have seen that the important factor in altitude is reduction in

the partial pressure of oxygen. All three of these methods accomplish this, and, therefore, so far as results are concerned it is merely a matter of convenience which method is adopted. A series of experiments carried out on all three apparatuses, on the same subjects show identical results. In the United States we use

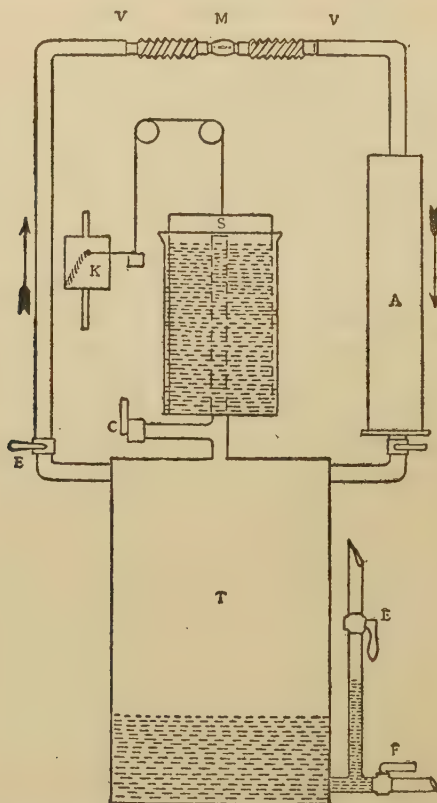


FIG. 19. SCHEMATIC REPRESENTATION OF THE HENDERSON REBREATHING APPARATUS (FROM THE AIR SERVICE MEDICAL)

the rebreather exclusively for testing pilots and both rebreather and low pressure chamber for experimental work. This test (rebreather) was devised during the war at the Medical Research Laboratory of the Air Service for classifying the Army flyers. Those responsible for the technique of the test were chiefly Schneider (5) and Dunlap (2). The low pressure chamber has an advantage in that the sub-

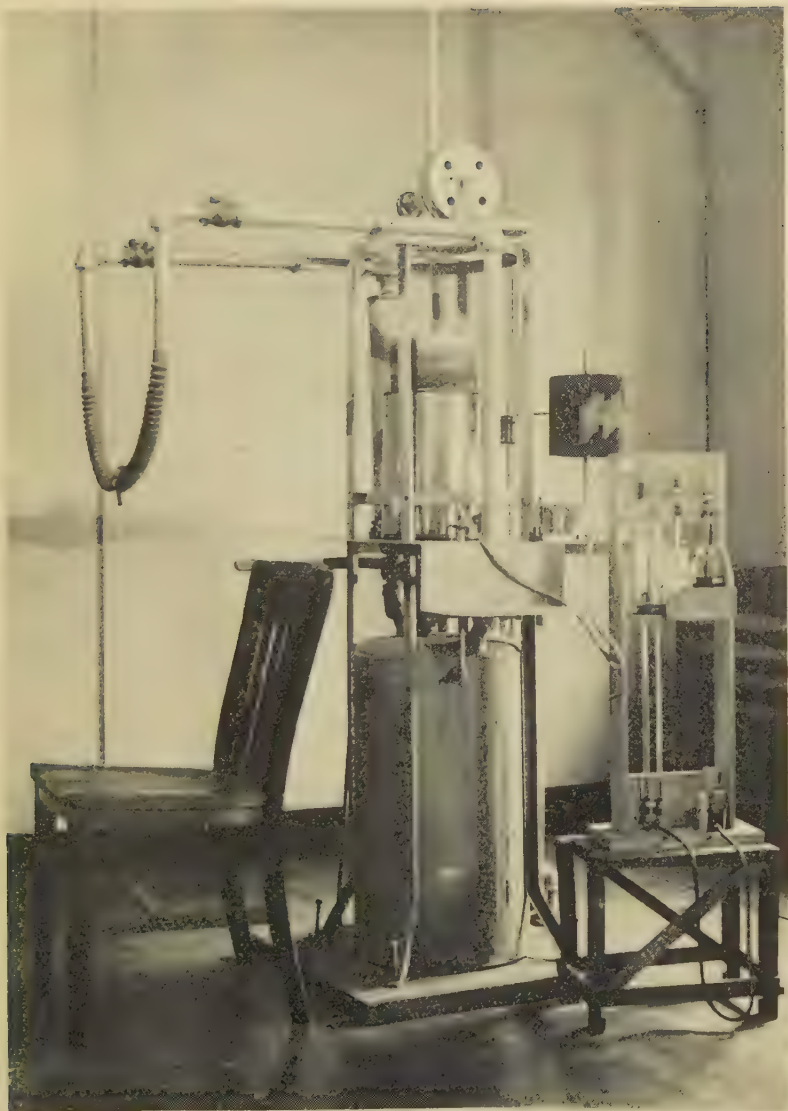


FIG. 20. THE HENDERSON-PIERCE REBREATHING, GAS ANALYSIS APPARATUS
AT RIGHT

ject can talk and move about, whereas on the rebreather he must sit in one position, and is unable to talk on account of the mouth piece and nose clip.

The Henderson-Pierce rebreather, which is the machine ordinarily used, consists of a steel tank with a wet spirometer at the top properly counterbalanced. There are inlets and outlets for both air and water. The amount of water determines the amount of air used in the experiment. We have found it convenient to use 52 liters of air in the standard test, and each machine is carefully calibrated so that it can be set to contain the exact amount of air at the beginning of each run. The spirometer is the only flexible part of the machine. It moves up and down during the test, its excursions being recorded by means of a stylus on a revolving drum of a kymograph. The inspiratory movements of the spirometer also rotate a Larsen respiration integrater which records the volume of respiration in deciliters. On either side of the tank is a metal pipe, one being an inspiratory pipe the other an expiratory pipe. There is a one-way flutter valve in each pipe which prevents the current of air from going in any but the right direction. In the expiration pipe there is placed a cartridge of dry sodium hydroxide molded in boat form, which removes the carbon dioxide from the expired air as it passes through it. Both pipes are connected with flexible rubber tubes at the distal ends which are in turn connected with a mouth piece. A nose clip is placed upon the nose, the arrangement being somewhat similar to that of a gas mask. The tank is fitted with valves so that the subject may breathe either air from the tank or the room as is desired. When the test starts the valve is turned so the subject is connected with the tank and he remains so connected until the end of the run when the valve is immediately closed. The tank and pipes are carefully flushed, removing the dead air before a run is started. As the carbon dioxide is absorbed and the oxygen burned up, there is less air in the tank as the run progresses, consequently the spirometer falls. This is corrected by letting in water from time to time during the course of the run, thus forcing air from the tank into the spirometer without altering the composition of the air of the test. Before the test begins the subject is given a physical examination. This consists in taking his history, particularly with reference to his aviation and athletic records and any altitude symptoms he may have experienced. His heart is carefully examined and a circulatory efficiency test performed.

He is then taken to the altitude test room and seated before the rebreather. His pulse and blood pressure, both systolic and diastolic, are taken in each of three consecutive minutes and are used as normals for comparison. He then receives instruction in the psychological part of the test (described later). The mouthpiece and nose clip are adjusted and the stop-watches of the observers are started as the valves are turned so that the subject is breathing air from the tank. The Larsen respiration integrater is read at the end of each minute and the number of deciliters breathed recorded. Any increase or decrease in respiratory volume from minute to minute may thus be noted. The amplitude of respiration is recorded on the smoked drum. This drum also indicates whether there are any leaks in or out of the apparatus. The subject's left arm rests on a table at his side and a sphygmomanometer and stethoscope are attached to it. The radial pulse is counted once a minute throughout the run and the systolic and diastolic blood pressures are taken every other minute during the first sixteen minutes of the run and then every minute throughout the balance of the run. A clinician stands by and examines the heart from time to time during the run. He is responsible for the condition of the subject.

While this is going on, the subject undergoes a psychological test to determine the effects of low oxygen on the brain. As already seen in a previous chapter, the earliest effects on the brain are on attention and motor coördination. The apparatus consists of a table on which are two rows of two candle power electric lamps, seven in each row. These lamps are turned on individually every three seconds but in an irregular order, the light remaining lighted for one and one-half seconds. There are two rows of washers and screw heads below the lights, one washer and screw head corresponding in position to each light. The screw heads are in the center of the washers and are the rounded type. By means of a stylus, the candidate must touch the screw head corresponding to the light which flashes and must touch it before the light goes out. It must be a free hand movement, i.e., he must not touch his hand or arm while making contact. He must touch the screw head only, and not slip off onto the washer. When he makes an accurate contact a green check lamp lights, and if he slips off onto the washer a red error lamp lights. In addition, there is an ammeter above the board which has a dual control, one for the operator, one for the subject. The control is a rheostat. He is told to keep the ammeter

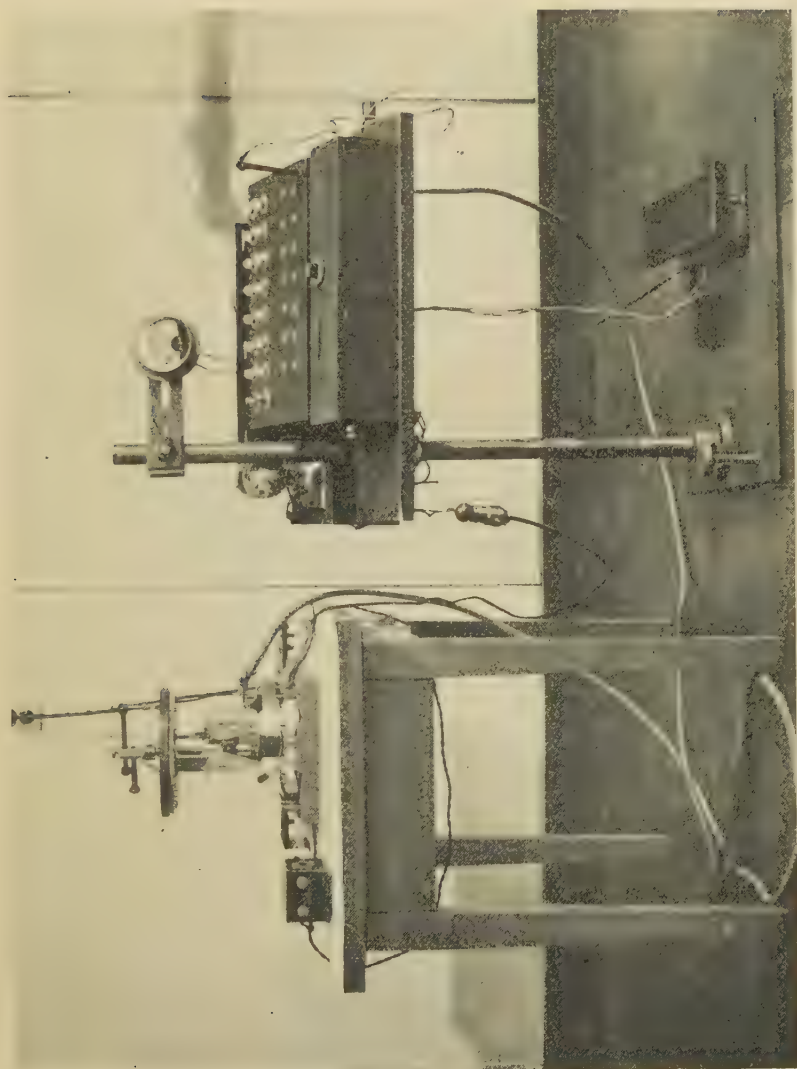


FIG. 21. THE PSYCHOLOGICAL APPARATUS USED IN THE REBREATHING TEST

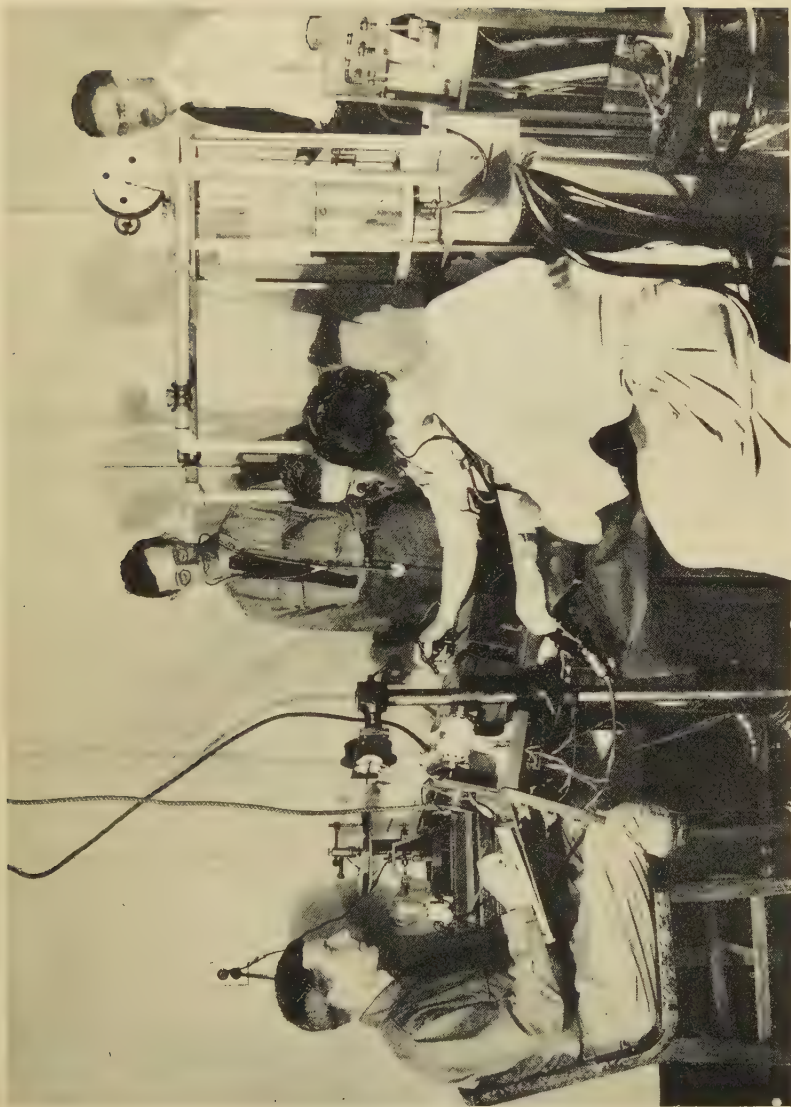


FIG. 22. THE ALTITUDE CLASSIFICATION TEST OF THE UNITED STATES AIR SERVICE (REBREATHER)

at a designated point which he does by moving the rheostat in the proper direction. The observer throws the ammeter off the designated point and the subject corrects it. There is also a motor having both low and high speed. The subject notes the speed of the motor by the pitch, a high pitch indicating high speed and a low pitch, low speed. He is instructed to keep the motor in low speed. The observer throws the motor into high speed by means of a switch and the subject throws it back by means of a rocking two-way foot switch which is under his right foot. The test is continuous and is a deterioration test. We desire to know what the effects of low oxygen are on the individual. The first three minutes of the run are taken, therefore, as a practice period, during which time the subject establishes his own normal. The psychologist notes by means of a set of symbols, the subject's reactions, paying particular attention to changes and deterioration from that normal. The lights are of primary importance and constitute a continuous test; the ammeter and the motor are used at intervals for the purpose of distraction and are secondary in importance to the lights. Inasmuch as each subject establishes his own normal at the beginning of the run, practice is not a factor in the test as he is rated psychologically purely on his performance during the test as compared with his normal at the beginning of it. The test is continuous and therefore the subject does not have the opportunity to rest and thus gather himself together for a new spurt. Fatigue does not enter in; and the test is rapid.

The following reactions are noted. A gradual increase in volume of respiration, in the optimum type of subject an increase of five liters and often more. The pulse rate may show no change until about the fifteenth minute when it will gradually increase or it may increase gradually from the start, increasing more rapidly toward the end of the run. Blood pressure holds on a level or toward the end of the run there may be a slight terminal increase in the systolic and a slight terminal decrease in the diastolic, thus giving an increased pulse pressure. In subjects who are susceptible to emotional influences, there is frequently marked increase in both pulse and blood pressure as the run starts. As the subject settles down to work and his first excitement wears off they tend to return towards normal. The heart shows little change as a rule. Towards the end of the run the sounds may become more accentuated. Sinus arrhythmia and extra systoles if present tend to increase during the

early part of the run and then disappear as the heart rate accelerates. Psychologically the effects are a restriction of the field of attention with resultant inability to attend to so many things at once, easy distractibility and loss of control over the finer movements. The first psychological symptoms are noted at about the fifteenth minute when the subject has reached an equivalent altitude of about fourteen thousand feet. He then usually improves, beginning to deteriorate again, this time more markedly, at about the twenty-fifth minute. He will let the motor run at high speed, he may neglect his ammeter, he is sluggish in responding to the lights, shows confusion, inaccuracies and motor incoördination. Eventually he becomes wholly inefficient and is taken off the machine. After two or three breaths of fresh air he is normal again, frequently asks why he was removed and is loathe to believe that he was not performing everything in first class fashion. Occasionally he may show other reactions, such as silly laughter, anger and even destructiveness at the end of the run.

The air in the tank is analyzed at the end of the run to determine the exact percentage of oxygen. The physiologist then grades him according to the reaction of pulse, blood pressure, respiratory volume and oxygen percentage attained. The clinician grades him according to the heart reaction. The psychologist grades him according to time of appearance of first symptoms of deterioration, time of the appearance of marked symptoms of inefficiency, length of run and percentage of oxygen attained.

When the rebreather examination was first developed, a routine eye examination was conducted during the test (1), a careful preliminary examination of the eyes having been made in each case. The psychological test was stopped while the eye test was made. At the beginning of the sixth minute of the test the convergence near point, the accommodation near point and the field of binocular fixation were noted. They were tested again every third minute and vision was tested every six minutes. At least one reading was made after the test was ended.

The changes found have already been discussed in the chapter on the eye. This section of the test was afterwards dropped as the information obtained was not considered of sufficient value to warrant the use of the additional observer.

With this standard of 52 liters of air, the average time of run is twenty-five minutes and the average oxygen per cent attained seven.

The grades are A, B, C, and D, the lowest grade given by any one of the three observers determining the final class. Class A is unrestricted as far as altitude is concerned; class B restricted to 15,000 feet, Class C to 8000 feet and Class D is grounded as unfit to fly. Of the first three classes about 61 per cent are graded A, 25 per cent B and 14 per cent C. These grades correspond roughly to the needs of the service. Combat work, some reconnaissance and some photography are done at high altitudes, day bombing and much photography at moderate altitudes and night bombing and some

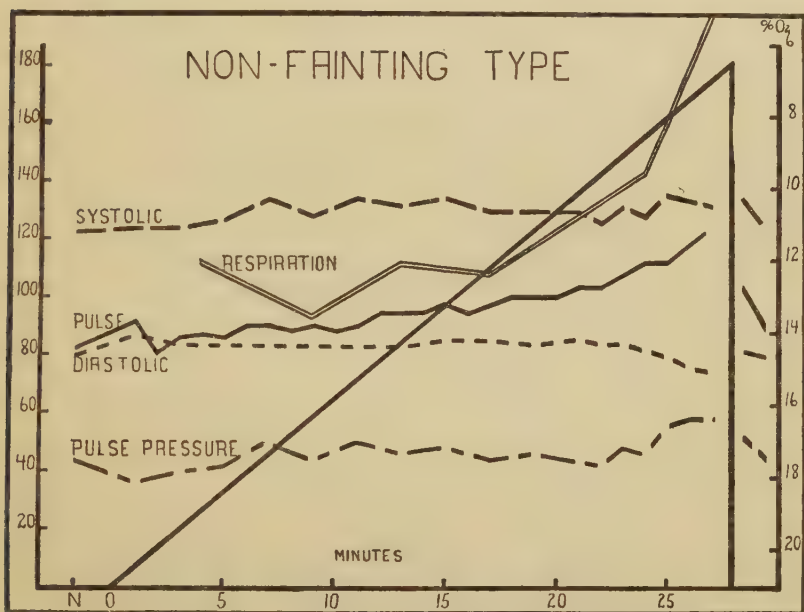


FIG. 23. CHART SHOWING THE NON-FAINTING TYPE OF REACTORS IN THE ALTITUDE CLASSIFICATION TEST (SCHNEIDER)

reconnaissance at low altitudes. When a flyer is restricted to a certain altitude by means of this test, it does not mean that he cannot fly above this limit. What it does mean is that he will not do efficient work above that limit. Repeated flights or work, at an altitude in excess of his limit place him at too great a strain and limit his efficiency.

The final rating of the subject depends upon how he adapts himself to the unaccustomed environment and upon how much circulatory strain is involved in preserving his efficiency. Some subjects

may compensate very well, preserving their efficiency to high altitudes, but they do it at the expense of such strain on the circulatory system that they could not be expected to last long. A subject who has a definitely diseased heart is put in Class D, and no man is put in Class A who fails to show good respiratory compensation or who shows circulatory reactions of such a character that severe strain on the cardio-vascular system is indicated.

The description of the reaction above is that of an optimum type. We have two general classes of reactors which are known as the fainting type and the non-fainting type. The above description is that of the non-fainting type. This type becomes inefficient psychologically before it does physiologically, in other words the subject will be removed by the psychologist because of mental inefficiency while the circulation is still holding good. Were he left on he would show a break physiologically in another minute, as a rule. In the fainting type the subject breaks physiologically before he does psychologically. He is removed by the clinician because of symptoms of circulatory collapse. The fainting type is divided into several groups. In one, which is perhaps the most common type, there is a sudden break in the diastolic pressure, in the second the break comes in the systolic, in the third in both systolic and diastolic together and in the fourth the break comes in the pulse rate. In any one of these types, unless the subject is given fresh air immediately, he will faint. In the fainting type there is usually a poor respiratory response as well.

Color reactions in the two types vary as well. In the non-fainting type there is flushing of the face, followed by gradually increasing cyanosis which continues to the end of the run. In the fainting type there is usually a paleness which persists throughout the run with a sudden turning to grayish pallor. In other cases there may be a slight cyanosis followed by a grayish pallor.

It will be found that practice does not benefit a man in so far as rating is concerned. His physical condition remaining the same, his rating will not change no matter how often the test occurs. With changes in his physical condition, however, there may be marked changes in his ability to compensate to altitude. The following two examples are cited to emphasize these points. One flyer was rated Class C. It developed that he had just recovered from an attack of influenza. He was ordered away on a month's sick leave and when he returned he was reexamined, this time re-

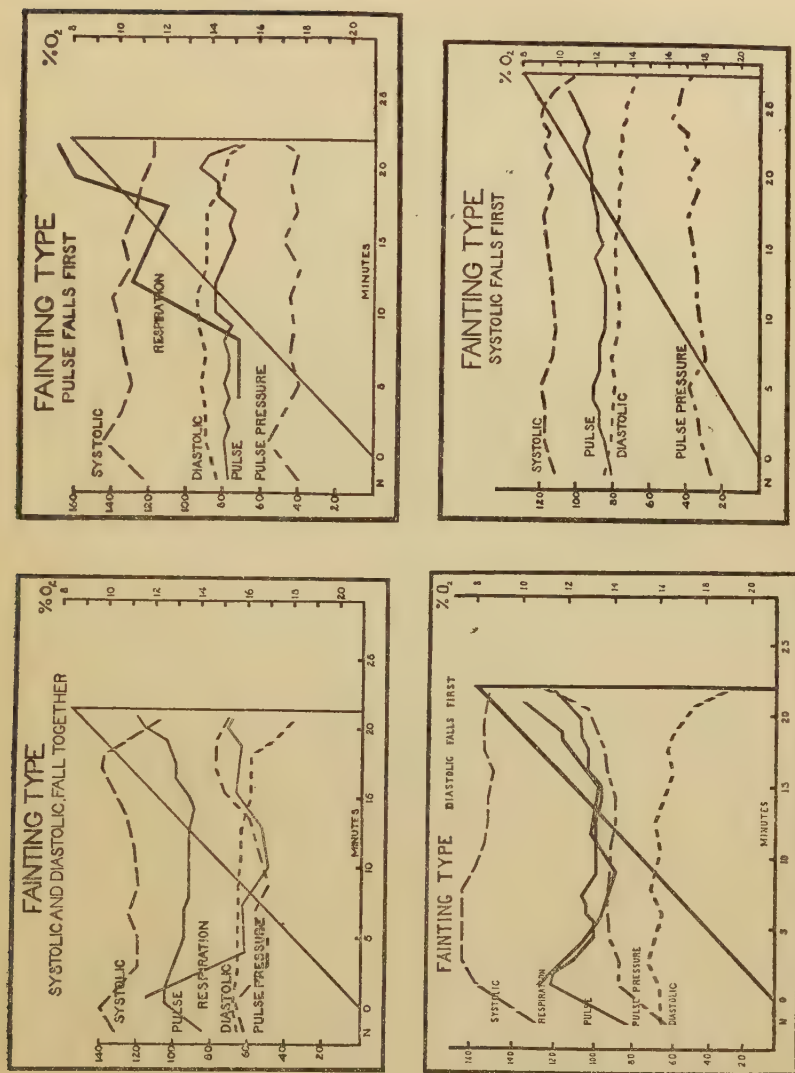


FIG. 24. CHART SHOWING FOUR FAINTING TYPES OF REACTORS IN THE ALTITUDE CLASSIFICATION TEST (SCHNEIDER)

ceiving the rating A. Another case is that of an officer who on several occasions had received a rating of A. He got in a run down condition and was rated a poor B. He went on leave which he spent out of doors with plenty of vigorous exercise and on return was reexamined and again rated A. The test, however, is not to be taken as a test for staleness or physical fitness but purely as a test for altitude fitness. Schneider (4) reports as a result of experiments in the American Expeditionary Forces that men may be physically below par, who may be tired and yet react very well to low oxygen. He states that there is remarkable variation in the individual to the toleration of low oxygen; some compensate well, some moderately and others not at all. The test should be employed for sifting out those unfit for flying by reason of inability to respond to altitude and for approximating the altitude successfully tolerated. It may be stated that every aviator should be examined on entrance to the service to determine his ability to compensate to the effects of altitude. This test should be repeated certainly once in eighteen months and in war time more frequently.

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CHAPTER X

OTHER ALTITUDE TESTS

Johnson and Paschal (3) endeavored to find a test that would furnish an objective measure of the extent of deterioration of behavior. The experiment was selected because it necessitated sustentation of vision, attention, memory and muscular coördination during longer time than a spurt would occupy. The subject was required to transliterate a number of sets of nonsense material into corresponding code, one being presented with each set of material. Codes were of equal difficulty and each letter of the alphabet was represented by a different letter of the code. The alphabet was given in the first line, the code in the second and the material to be transliterated below. The subject was connected with a rebreather and told that his performance depended upon time, accuracy and number of letters correctly substituted in the unit of time. There was a large practice factor noted, the rate and improvement varying with the subject's interest and distractibility. In some cases a subject showed definite deterioration at an oxygen tension of 15 to 12 per cent. This disturbance was sometimes compensated for by increased muscular activity. Two types of reactors were noted, those stimulated by oxygen deficiency, showing greatly increased speed at the expense of accuracy and those whose performance was retarded. The diminished speed was considered as a failure of muscular coördination and these subjects showed hard pressure with the pencil, inaccuracy, inability to form letters and sometimes inability to put pencil to paper. The authors felt that the test might serve as a substitute for the psychological part of rebreathing examination in experienced hands, although detection of initial disturbances was not as easy. In their conclusion they state, "The results of the test indicate that the sensori-motor reflexes, as a rule, do not exhibit noticeable impairment until deterioration of the more highly organized responses have reached an advanced stage." They suggest an hypothetical explanation that the deleterious influence of low oxygen on the subject's response is largely due to interference with the synapses. So far as is known, this test has never been put

to any practical application. The statements of the authors that it would prove of value only in the hands of experienced observers renders the test impractical for general use.

A test was developed fairly early in the war by Flack (2) which is known as the Flack Bag Test. The apparatus consists of a bag containing five liters of room air with a cylinder containing a carbon dioxide absorber attached to it, and a mouthpiece at the end of the cylinder. The method of performing the test is by filling the bag with air; the candidate then closes the lips firmly on the mouthpiece and breathes in and out through his mouth, at the same time holding his nose. He continues this until the amount of oxygen in the bag becomes so small that he is unable to stand it longer. The length of time is noted and a sample of the air in the bag examined for oxygen content. This was not always done. From these facts the determination is made of the altitude the man would be able to attain. A person of good physique and capable of withstanding altitude will persist for from three to three and one-half minutes and an analysis of the air remaining usually shows 6 or 7 per cent oxygen. Later the pulse was counted during the rebreathing, a careful estimate being made of the quality and rapidity. Later, but independently, the Dreyer nitrogen dilution apparatus was developed (1). This consists of an arrangement whereby pure atmospheric air or a mixture of atmospheric air and nitrogen could be passed into a breathing chamber and their relative proportions changed. It was for the purpose of holding a man at a level for a considerable period. Exactly the same results would be obtained by this apparatus as are obtained by the rebreather. So far as is known, neither of these tests is used at the present time in the routine examination of the flyer, although it is believed that the Flack Bag Test is used in special cases. A 7.5 liter bag is used now.

There is a series of tests which were developed by Flack for aviation candidates for the Royal Air Force, and they are outlined in the regulations of the Royal Air Force (4). These tests are designed to ascertain, (1) probable aptitude of the candidate for acquiring the art of flying; (2) likelihood of the candidate for withstanding the strain of continued flying especially at high altitudes, (3) temperamental aptitude of the candidate for combatant service in the air. Sufficient time should elapse between the tests and they should not be made for at least some hours after flying. Attention is directed to performance as a whole rather than to any single test. Only

those specially concerned with adaptation to altitude will be considered here. The tests for tremor, self balancing, balancing rod, measurement of reflexes, and time of psychomotor reactions have already been described in a previous chapter. The test for response of the pulse to exercise and examination of blood pressure will be described later in the chapter on tests for physical fitness. The tests to be considered in this chapter are as follows.

Vital Capacity. Preferably five observations should be taken and recorded in liters and fractions of a liter. The subject sits opposite the spirometer, the dial being so placed that he cannot see the readings. Neck, chest and abdomen must move freely. He is directed to fill his lungs to their maximum capacity, and then, while holding his nose, to expire as completely as possible at a fair rate through the meter. The adequacy or otherwise of the vital capacity for the weight, stem-length and chest circumference of the candidate can be found by reference to tables published by Professor Dreyer.

Breath-Holding Test. The subject is asked to expire as deeply as possible (preferably audibly) to fill the lungs fully (but not to discomfort), and to hold the breath as long as possible with the nose clipped. Record the time for which the breath is held. The subject examined must not be told the significance of the test, nor the time that he is expected to hold his breath. On no account may he time himself. When he gives up he should be asked his reason for ceasing. Normally an answer such as "I felt I should burst," "I wanted to breathe," is given. Individuals suffering from marked disability at great altitudes almost invariably return an abnormal answer, e.g., "I became dizzy," "things went blurred." Where an answer is deemed abnormal the exact words should be recorded. The average time the breath is held by the normal fit pilot is 69 seconds. This test is believed to afford indications of:

1. The stability of the respiratory center and indirectly of the nervous system generally.
2. The likelihood when the time is short, and an abnormal answer is given, of the subject suffering from oxygen-want at great altitudes.
3. Resolution to "carry on" under difficulties.

Expiratory Force. The subject is instructed to hold his lips around the mouth-piece with the thumb and forefinger of each hand, at the same time pressing against the cheeks so that they take no part in the performance of the test. After drawing in a full inspiration through the nose, he is told to blow the mercury steadily as high as possible, strongly contracting the abdominal muscles during the process. On no account must the subject be allowed to swing the mercury up violently. The reason for holding the cheeks is that it has been found that in some cases the mercury may be forced up to abnormal heights by the action of the cheek muscles. The number of mm. Hg reached by the subject's best effort is recorded. The average for normal persons is about 110 mm. Hg. When under 80 mm. Hg it suggests that the subject will probably be incapable of sustaining effort.

Endurance Test (40 mm. Hg U Tube Test). With the nose clipped, the candidate is asked to empty the lungs completely, inhale fully, blow the mercury to the height of 40 mm. and maintain it there without breathing as long as possible, the pulse being counted in periods of five seconds during the performance of the test. The average time in a large number of cases tested is between fifty and sixty seconds. A time less than forty seconds is very unsatisfactory. In a good subject the pulse rate may remain practically unaffected or may rise gradually in rate from 72 to 96 according to the time the breath is held. The pulse may rise almost at once from 72 to 84 or 96, and be sustained there. A large rise in rate, e.g., from 72 to 132, or 144, is unsatisfactory, and is held to be indicative of abdominal venous pooling. In cases of marked physical inefficiency a characteristic response is for the pulse to jump up to a very quick rate, e.g., 132 to 144, during the second or third period of five seconds and then to fall away in rate to normal or even below normal. Such cardio-motor instability is an adverse factor in aerial work, and is an indication for rest. The test to be recorded thus: First, the number of seconds during which the mercury column is sustained, then the normal sitting rate per five seconds taken before beginning the test, and then the number of pulsations in each five-second period, the time taken to blow the mercury to 40 mm. being ignored. The normal sitting rate should be separated by a stroke from the first figure of the pulse response during the test, e.g., fifty seconds 6/6677789888. This test affords information as to the stability of the medullary centers and of the power of resistance to fatigue.

In the original test for vital capacity no account was apparently taken of the size of the man and a minimum vital capacity was given as three liters. As will be seen from the description of the present test the adequacy of the vital capacity is determined by reference to Dreyer's tables for the assessment of physical fitness. Schneider (5) in the examination of 128 men with both rebreathing tests and English tests has found little correlation between vital capacity alone and the compensation necessary in oxygen want. He found that men with small vital capacity reacted as well to oxygen want as men with greater vital capacities, although none of them reached very low oxygen percentages. The man with the largest vital capacity compensated rather poorly.

In the breath holding test the average of a good pilot was originally given as sixty seconds and it was maintained that all should be able to hold the breath a minimum of forty-five seconds in three attempts. As will be seen above the average time a breath is held by the normal pilot is sixty-nine seconds. No minimum is given. In a correlation by Schneider with a breath holding ability and endurance to low oxygen there did not appear to be very close relationship. Of ten men who were able to hold the breath only forty-five seconds or

less, six of them reached 6.5 per cent oxygen on the rebreather. One who held his breath for sixty-nine seconds was only able to reach 11.1 per cent oxygen. Another who held his breath ninety-nine seconds showed circulatory failure at 10.7 per cent oxygen.

In the respiratory force test Schneider found again a poor correlation with the ability to endure low oxygen, although the correlation was a little higher than was the case with vital capacity and breath holding. Three men whose expiratory force was only 70 mm. compensated to 8 per cent or better. Four others whose expiratory force varied from 110 to 140 mm. compensated only to approximately 10 to 11 per cent oxygen.

In the endurance test the correlation of the endurance to low oxygen was about the same as that of the breath holding test. In this test Flack considers that one of the important factors is the pulse count during the effort. While this was done by Schneider, his results are based on breath holding only, without regard to variations in the pulse, as he found the data on the pulse rate could not be stated in a correlation tabulation.

A further test was formerly used by the British known as Bazett's (5) respiratory reserve factor, figured by the following formula:

$$\frac{\text{Consumption of air per minute} \times \text{respiratory rate}}{\text{Vital capacity}}$$

He believes that a large vital capacity accompanied by a low consumption of air and a low respiratory rate indicate a better ability to endure high altitudes, than other factors. His figures were, for a good type of flyer 24.1, for bad 46.3 and for the uncertain 36.8. The figure of 30 was taken as a standard. Here again Schneider found a rather poor correlation.

Schneider also reports a certain ability to improve results by practise in these tests and also claims that they require too much coöperation on the part of the subject. In assessing the value of any test or set of tests one must consider other factors than scientific accuracy. The question of time is very important. In war time thousands of men have to be examined and one cannot adopt a prolonged test involving the use of a large personnel, no matter how satisfactory the test, unless the necessary professional man power is available. The question of available medical officers alone, for instance would probably prevent the British from adopting our rebreathing test because this test including the preliminaries con-

sumes the better part of an hour, and during half of that time it necessitates a personnel of at least four. For use in the United States Air Service we feel that the rebreather is by far the most satisfactory test for determining the ability to compensate to the effects of altitude.

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CHAPTER XI

THE EFFECTS OF WIND, COLD AND SPEED

THE EFFECTS OF WIND

Wind constitutes one of the most disagreeable factors in flying. A current of air caused by the propeller results in a strong blast of air being directed against the pilot. Many of the planes carry windshields which are a great comfort. However, the pilot frequently sticks his head out beyond the wind-shield, particularly when checking up his map, examining the terrain or perhaps to look at something about his motor, or in case the wind-shield becomes fogged with moisture or oil. Travelling at high speed, if the pilot turns the side of his face toward the wind blast, it will close up the nostril on that side. If he opens his mouth it will balloon out his cheeks and he will have difficulty getting his lips closed again. Unless the helmet and goggles are securely fastened, they will be blown off. If he flies without a helmet, the effect of the wind blowing his hair is such that his scalp will be numb for some time afterward. Headaches and dryness of the throat are complained of in this connection particularly with beginners. The question naturally arose as to whether or not such strong wind would modify the breathing function.

Experimental work on this point was carried out by the Italians, particularly by Aggazzotti and Galeotti (1) who conducted experiments in airplanes, on tops of mountains and with artificial wind. As a result of their experiments, they found that wind produces alterations in breathing consisting in irregularity of rhythm, acceleration of rhythm and unevenness of various breathing acts. In general, they found that lung ventilation is favorable, provided the wind is not too strong—above 30 or 40 km. per hour. As a result of the increased lung ventilation there is a decrease in the alveolar carbon dioxide. They found the latter phenomenon more distinct and constant at great heights and here as well they found a decrease in the carbon dioxide of the blood resulting in a state of *acapnea*. They conclude that the pilots should have their faces

protected from the wind, especially those going to great altitudes because the effect of wind is to increase disturbances due to falling barometric pressure. They suggest that stronger winds than they experimented with may interfere with the entrance of air to the lungs, hinder movements of the thorax and decrease lung ventilation.

They also carried out experiments to determine the effect of wind on the pulse, using the same methods that they used in the breathing experiments. They found both acceleration and slowing up of the pulse together with unevenness in rhythm, modification of the sphygmie wave and reinforcement of the cardiac pulsation. All these changes they considered as reflexes.

Geigel (3), in experimenting on the effects of wind and breathing, particularly with reference to expiratory force concludes that an expiratory pressure of at least 130 mm. should be required for flying service. He claims that the results of his experiment show that the contrary wind surpasses the speed of travel and that the difference is due to the current of air which the propeller produces. With a speed of travel of 110 km. per hour, he found the contrary wind amounted to 40 meters per second. He assumes that with a speed of travel of 220 km. per hour the contrary wind will amount to 80 meters per second. He believes pilots would only just be able to maintain respiratory balance at this speed. If one is breathing against a wind pressure it will require a certain additional amount of expiratory force to expel air from the lungs: he claims, therefore, that it would be possible to face a wind too strong to permit expiration. However, the wind force would help collapse the chest in the act of expiration and the chest wall would be subject to the same pressure internally and externally. It is not seen, therefore, how the force of the wind could ever prevent respiration.

It is known that air movements favor cooling of the body. Schneider (4) states that a breeze of 15 miles an hour at a temperature of 59 to 68 degrees will increase metabolism 19 per cent. Metabolism will usually be increased by the effect of wind during flying and increases the demand of the body for oxygen.

THE EFFECTS OF COLD

The average temperature of the atmosphere decreases as we ascend, according to the following tabulation:

During the first mile of ascent the temperature falls 1°F. in every 540 feet of ascent

From 14,000 to 16,000 feet the temperature falls 1°F. in every 360 feet of ascent

From 23,000 to 29,500 feet the temperature falls 1°F. in every 188 feet of ascent

From 32,500 to 39,500 and beyond the temperature remains quite constant at approximately 62° below zero in summer and 71° below in winter.

The intensity of cold the aviator experiences varies with the season, climate, altitude attained and with the speed of flying. Schneider (5) states that in flight the cold increases by stages. First, there is a sensation of chilling, a development of goose pimples, and pallor; with sufficient protection the reaction stops here, otherwise the chilling accentuates, there is development of painful sensations, and the extremities become stiff followed by numbness and a tendency to sleep. This fall in temperature stimulates metabolism of the body and, therefore, the demand for oxygen is increased. At high altitudes, then where the temperature is low we have not only diminished oxygen supply but an increased demand for oxygen. Older men are more sensitive to low temperatures and have less power to react than young men.

EFFECTS OF SPEED

The Pulitzer race in 1923 was won at a speed of 243.7 miles per hour. Later in the same year an official speed of approximately 266 miles per hour was attained by the same flyer, Lieutenant Williams of the United States Navy. Much discussion at once arose as to how fast a man could fly and still live. The winner of the Pulitzer trophy in 1922 is said to have stated that he became unconscious when making turns. The winner in 1923 is said to have been in more or less of a daze. That he must have been is evidenced by the fact that he went around the course an additional time, not being sure how many laps he had completed. What is the explanation of this? It is believed the answer is centrifugal force. The reader has undoubtedly experienced the sensation of travelling around a curve at high speed in a railroad train. If the curve is to the left, there is a tendency to fall to the right, or in other words, centrifugal force acts in the direction in which the train was originally going. When the pilot is flying a straightaway course, his body is upright in the sitting posture and the plane horizontal.

When a sharp turn is made, for instance to the left, the ship is banked so the wings and the position of the pilot's body are practically at right angles to their former position. As the flyer makes a turn, the pull of centrifugal force which acts in the original line of travel is in the direction away from the pilot's head or toward his feet. The pilot being strapped into the machine, centrifugal force

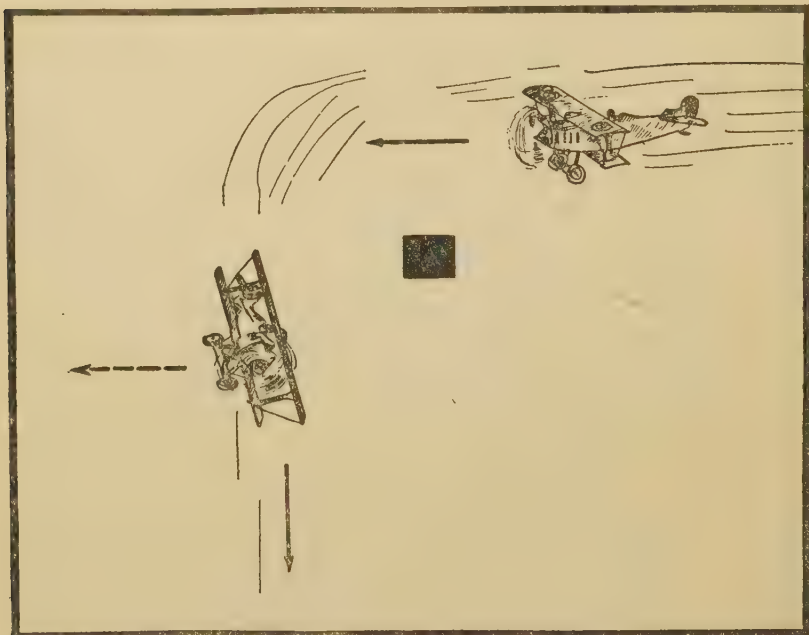


FIG. 25. SCHEMATIC REPRESENTATION OF CENTRIFUGAL FORCE ON AIRPLANE MAKING A SHARP TURN

The diagram illustrates the position of a plane while flying straight ahead and while making a sharp left hand turn. The straight arrows indicate the direction of travel before and after the turn. The dotted arrow indicates the direction of the centrifugal pull during the turn.

cannot pull him out of his seat but it does pull on his body and as a result everything that can, moves in the direction of the pull. This means that the blood is carried away from the head to his lower extremities and especially into the easily dilated splanchnic vessels. Anemia of the brain, resulting in haziness, dizziness and even unconsciousness results. Recovery is prompt because the circulation

readily adjusts itself to the new position of the body and the action of centrifugal force rapidly changes to the direction of the new line of travel. What the limit to speed will be, experience alone will show.

Garsaux (2) in experiments with dogs rotated them on a wheel at speeds varying from four to six turns per second. Some of the dogs showed actual injury to the brain from the brain being pressed against the skull. Recovery followed in some, death in others. Autopsies showed that there was an anemia of the brain and an engorgement of the vessels of the abdominal area, thus bearing out the above statements about the aviator.

It is, therefore, not a wild theory to presume that a speed may yet be attained which when a turn is made would be sufficient to cause pressure on the stem of the brain in such a manner as to cause death. Furthermore, the force of such violent action would be sufficient to rupture blood vessels both in the brain and in other parts of the body, which might be sufficient to cause death or lasting injury.

We talk of attaining the terrific speeds of 500 and even 1000 miles an hour. While such speeds may be mechanically possible in the future, it is very doubtful if a human being will be able to stand such speeds. A straight ahead speed will, of course, cause less effect than turning at the same speed and what the limit is, time alone will tell. So it may be said that a flyer may fly straight ahead at much greater speed than he can if he makes a turn, but it is doubtful if he will be able to withstand a speed of much over 300 miles an hour on sharp turns.

The sensations mentioned under the effects of wind, namely, tingling of the scalp, and ballooning of the cheeks are greatly accentuated at very high speeds. Travelling at 250 miles per hour, if the pilot should hold his arm out, it would at least be broken. Should he stand up with his head well above the cockpit he would be knocked over and his neck probably broken.

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SECTION III
THE CARE AND MAINTENANCE OF THE FLYER

CHAPTER XII

FATIGUE, STALENESS AND PHYSICAL FITNESS

We have considered in the two previous sections the selection of the flyer, his classification with respect to altitude and the general and specific effects of altitude, cold, wind and speed. We now come to another important phase of aviation medicine, namely, the care and maintenance of the flyer. The careful selection and classification of the flyer is of little value unless he can be kept in at least as good condition as when he entered upon his flying duties. It has been found that a flyer tends to deteriorate physically unless he is carefully supervised. To support this statement, the following evidence is given.

The English found that the stress of work at the front during the war meant a limited amount of work, that the limit of every flyer was approximately one hundred and fifty to three hundred hours. At the end of this time the condition of the men was such that they were permanently taken off flying. It is essential that the physical mechanism of the flyer be such that it can withstand a strain of the worst kind.

Birley (3) states that all flying is, in a sense, fatiguing in that it demands attention, but that the fatigue experienced is in inverse proportion to the skill of the pilot and the efficiency of the airplane. He adds that flying at altitudes from 13,000 to 15,000 feet has a factor which definitely accelerated the onset of nervous fatigue. He states that the most important psychological factor is the individualism of flying.

Dudley (7) states that pilots should be watched carefully by medical officers and should be given leave before rather than after signs of staleness appear, that nervous exhaustion and the time it takes to appear depend on (a) temperament and habits of the individual, (b) type of work and machine used, (c) prevailing weather conditions, (d) environment of the airdrome.

Experience has shown that a flyer becomes stale from too much flying, from too little exercise, from dissipation and repeated loss of sleep.

FATIGUE

It will be well at this point to consider what fatigue really is from the physiological standpoint and what factors induce fatigue in the flyer. Schneider (19, 21) defines fatigue as "a progressive flagging of efficiency together with subjective sensation of loss of control of the muscles." There is a depression of physiological activity, mental or physical. Subjectively, there is first a feeling of local tiredness in the active muscles and finally sleepiness. Objectively, there is a diminished capacity for work.

He states that fatigue may be normal or healthy when it is the result of mere activity and normal condition is restored by one night's sleep. Accumulative fatigue is accompanied by disordered metabolism when the activity is so excessive that more than an ordinary period of rest is required for recovery. Fatigue may be due to a lack of energy, resulting from decreased oxygen supply, lack of carbohydrate or water, or it may be due to an accumulation of the chemical end-products of metabolism.

Bainbridge (2) states that there are two types of fatigue, one originates entirely within the nervous system, the other arises partly in the nervous system and partly in the muscles. The former is common, the latter infrequent.

STALENESS

In accumulative fatigue or staleness, the output in work is greater than the income, according to Schneider (21). Staleness may be caused, according to the same author, by doing so much in one day that it takes several days to recover, or by doing just enough more each day than can be recovered from at night. Thus the reserve of the body becomes exhausted. He states that staleness is a neural condition founded on chemical conditions within the body.

Schneider (21) defines the various types of staleness as follows:

- (1) Cardiorespiratory—pulse increase in rate, poor in volume and low in tension. There is distress on slight exertion accompanied by an inordinate rise in pulse rate and prolonged time of return of the pulse after exercise; breathing shallow and rapid; extremities poor in color, cyanotic and cold.
- (2) Nervous type—Poor muscular control of balancing movements; fine tremors of the hands, eyelids and tongue; apprehensive starts with sudden sensory experiences; disturbed sleep, loss of sleep, nightmare.
- (3) Muscular type—Tenderness of the muscles with loss of tone, flabbiness, loss in power which may be marked or slight. These symptoms may be confused with rheumatism.
- (4) Staleness may be brought about also by disorders of diges-

tion characterized by removal of normal inhibitions, i.e., response to sensory stimuli by excess of motion, hypersensitiveness, annoyed by bright light, little noises, etc., restlessness.

Bainbridge (2) terms staleness "effort syndrome" and characterizes it as a condition arising from severe exertion or in the course of physical training accompanied by a lessened capacity of performing work and by exaggeration of the respiration and circulation changes normally occurring. He believes the contractile power of the heart is below average and either the muscles or the nervous system suffer from oxygen want. The increased respiration, pulse and blood pressure from the inadequate supply of oxygen.

The causes of fatigue and staleness in the flyer are numerous according to the experience of several authors. Continued flying at high altitude, according to Birley, is one cause. He found that the heart mechanism becomes over-irritable, blood pressures in severe cases are subnormal, there is shortness of breath on exertion, and palpitation. Exercise lowers the arterial pressure instead of raising it.

Flack (8) states that flying results in stress in the aviator, especially at high altitude. Breakdown is frequent and subjects suffer from gradual loss of power of flying at high altitudes, accompanied by symptoms of cardiac and nervous upset.

Flack and Bowdler (9) consider that there is an enormous strain on the cardiovascular and nervous systems particularly during the first solo flight and when flying over the enemy lines. They emphasize the necessity of selecting the candidate whose cardiovascular and nervous stability should be of a sufficiently high standard to allow a margin for the stress of training and subsequent service.

Cruchet (5) believes that fatigue is a result of cardiac distress evidenced by hypertension and later a failing of the heart unadapted to exertion accompanied by hypotension.

Von Schjerning (23) attributes the trouble to the mental shocks which the aviator experiences in his work. He cites the experience of seeing an associate killed in a wreck, of the strain that he is under when his associate has been killed by a bullet, when the plane is damaged, when the plane fails to respond, etc. Aviation in general, in his opinion, causes a great excitement. He considers that in the selection of the aviator careful attention should be given to eliminating those who in their previous history showed no resistance to stress. He states that those who failed in their flying were either

of nervous disposition or who had never gone through any special excitement. Knowledge of personal history would have prevented accepting those men. He found that there are some who as a result of long continued stress become sick from nervous exhaustion either slowly or in conjunction with a physical or psychical accident. He states that the breaking down of this class could have been prevented if they had had medical advice at the time.

That mental fatigue may be a factor in accidents is shown by its symptomatology. It is characterized by Schneider (21) as presenting diminishing attention, difficulty in concentration, slowness in reaction to sensory stimuli, difficulty in reasoning and slowness in calculation. In a conference with 89 observers from the front, it was brought out that these observers agreed that staleness is a mental and physical depression brought about by the monotony of being constantly in the airdrome with long hours in the air. It is characterized by loss of appetite, general debility and a dread of the future. There is jumpiness and loss of ambition. The necessity of being on the alert much of the time results in a telling nervous strain.

Patten (15) describes staleness as a mental and physical condition manifested in various ways, such as loss of appetite, disturbance of sleep by bad dreams, inability to keep the mind on work, apprehension, nervousness, restlessness and loss of flying judgment, alertness and keenness.

Birley (3) describes a typical picture of a stale flyer. He complains of having lost some of his keenness, he is discouraged with his work, he is not sure of himself in the air and he loses flying judgment, his appetite is poor, his sleep is less sound and he dreams of unpleasant flying experiences. He has to force himself to go into the air. He is irritable, short of breath and he attributes his condition to trivial causes. If it goes on, the worse his condition becomes until eventually he must be grounded not only temporarily but permanently.

Gilchrist (10) believes that most cases of breakdown occur in pilots with a poor family history and a personal history showing various nervous conditions in childhood or later.

Anderson (1) considers the condition an "aeroneurosis" and believes that it may be either of a neurasthenic or of an hysteric type; that it may occur at any time during the period of training. It may occur during the first solo flight, following an accident or

injury, or following the witnessing of an accident. Some of them admit that they do not want to go on with their flying and others claim the opposite.

Gotch (11) believes it essential to make a very careful examination from the standpoint of family and personal history. He believes that the neuroses frequently may be traced to heredity or a previous nervous affection in the individual. He classifies the cases into six groups: (1) Those simply physically or mentally tired; (2) those in whom the breakdown is from a purely mental origin due to some unpleasant experience (the majority of cases come in this group; (3) the toxic group; (4) the psychopaths; (5) the purely physical group as opposed to the mental (this results from oxygen want, air sickness, heterophoria, etc.); (6) malingerers.

In the first group a subject merely complains of being tired and stale and of the fact that he can no longer make good landings, that his flying is falling off. In the second group the central nervous system is in a state of disturbance. There is depression, apprehension, irritability, change of character, a desire to be alone, lack of concentration, energy and interest, defect of memory, sleeplessness, unpleasant dreams. Physically there are complaints of breathlessness, fatigue on exertion, palpitation, headache, excessive perspiration, tremor, increased reflexes, possible development of stammering and tics. In the third group the symptoms are fatigue, weariness of the limbs, exhaustion and mental dullness. The fourth, and sixth groups are not true aeroneuroses, as their condition is not directly attributable to flying. The fifth group shows a symptomatology varying with the cause.

We have, then, a definite condition developing in the flyer as a result of his air work. This condition is characterized by mental and physical symptoms and signs which closely simulate the condition known as neuro-circulatory asthenia or effort syndrome. The typical case shows loss of interest in work, constant fatigue, distress on slight exertion, poor muscular control, nervousness, inattention and carelessness. Cases already described are a result of war flying. We find, however, the same condition resulting during peace time. It may be due to excessive flying, although excessive flying in peace time is rare. As a general rule, however, flying more than four to six hours a day is excessive and even flying this much day after day will result in staleness unless there are intervals of rest from time to time. High altitude flying unques-

tionably causes it if persisted in day after day without use of oxygen. Persistent high altitude flying, however, is not common during peace time. Dissipation may cause it, continued loss of sleep and constant excesses deplete the reserve of the individual and his flying suffers.

Lack of exercise is a factor. The condition of staleness in the aviator has been likened to the staleness of the athlete. Every one is familiar with the football player or the track athlete who suddenly becomes stale and whose efficiency is lost. The condition in the flyer is the same but results from a different cause. The staleness of the athlete develops from too much exercise, while in the flyer it results from too little exercise, from mental strain, dissipation, excess flying, repeated oxygen want at high altitudes, or from a combination of these.

There is no question but that flying is a strain. Even experienced pilots are undergoing a constant strain while in the air, although it may be unconscious. This constant strain results in great wear and tear on the nervous system. As a result, unless the physical condition is kept up to par, something will crack.

The physical and mental symptoms which the flyer presents are accompanied by a falling off in his flying ability. One of the first things to be noticed is an inability to make a good landing. His judgment of distance has become poor and examination by the depth perception test will reveal that his depth perception has fallen off markedly. His judgment has become poor, he becomes reckless or over-cautious. He loses pleasure in flying and later becomes unwilling to go into the air and literally forces himself to do it. That this condition is a real neuro-circulatory asthenia will be seen from the following description of that condition.

EFFORT SYNDROME

The term "effort syndrome" emphasizes the out-standing feature of the condition, namely exaggerated response of the circulatory and respiratory systems to physical effort. Lewis (12) was the first to describe this condition. The classification is as follows: (1) The constitutional type. In this type heredity plays an important part. A careful study of the family and of the subject will usually eliminate this group. (2) The second group. In this type the symptoms are brought on by exposure, work, mental and physical strain. This is the class with which we have to deal largely

in the Air Service. There is a third group which represents those cases which are convalescent from illnesses and the fourth or toxic group.

The symptoms are, in the order of importance, breathlessness brought on by exertion, the rate of breathing being markedly increased by exercise; pain, which is anything from a precordial soreness to an anginal pain, this is usually exaggerated by exercise; exhaustion, even mild cases show fatigue on moderate exertion and in severe cases exhaustion both mentally and physically may result; palpitation is common; giddiness is more or less constant and is associated with change of posture and effort; fainting may occur; other symptoms are headache, lassitude, irritability, sleeplessness; inability to fix attention, coldness of the hands and feet, sweating, particularly of the hands, feet and axillae.

The physical signs are increased heart rate and particularly an exaggerated response of the heart rate to exercise and a slow return of the pulse after exercise. There are exaggerated responses of the blood pressure although frequently we find that upon change of posture the blood pressure falls rather than rises. The apex beat may be diffuse and the heart sounds accentuated. Functional systolic murmurs may be present. There is an exaggeration of the deep reflexes and coarse tremor of the hands and tongue. The symptoms of any individual case may be anything from breathlessness up to a definite picture presenting the above symptoms. The stale flyer presents much the same picture. The flight surgeon should be continually on the watch for the development of this condition. It must be caught in its incipency for if it is allowed to develop not only may a serious accident occur but recovery becomes prolonged and uncertain.

Again attention must be called to the importance of making a careful neuro-psyche examination as outlined in the first section of the book. The elimination of a large number of cases presenting unfavorable family and personal histories will reduce largely the number of cases of staleness particularly of the most unfavorable type. A careful supervision of the work and the physical condition of those who are selected will obviate the occurrence of these cases or will detect them in their incipency before damage is done.

PHYSICAL FITNESS

One of the methods by which this may be accomplished is by placing emphasis on physical fitness. Physical fitness necessitates muscular exercise. Everyone needs exercise, and general exercise is needed for the maintenance of health. Schneider (21) states, "All parts of the body are benefited by exercise and no part is better benefited than the nervous system."

Bainbridge (2) states that regular and progressive exercise is the essential feature of training. Training develops the skeletal muscles and also the heart. In a trained individual the pulse is slower, the blood pressure lower and the minute volume of the heart smaller than is the case with the untrained individual. The same author asserts that these same differences are due to the greater output of the heart per beat, and greater coefficient of utilization of the oxygen carrying power of the blood. There is better coördination of movement which improves the mechanical efficiency. The work done is performed with greater economy of effort.

Schneider (20, 21) reports that the effects of training result in increase of the size of the muscles, increased muscle power, increased facility of nerve impulse to the muscle and better coördination of the muscles. The heart muscle becomes larger, its nutritive condition is improved and there is a more efficient coronary circulation. The heart rate is less rapid following exercise. The rate comes down rapidly, while in the untrained it is slow in returning. The blood contains more oxygen and the hemoglobin content is increased up to ten per cent. Breathing becomes deeper and less rapid. The body as a whole has increased its efficiency. There is less consumption of fuel, there is smaller consumption of oxygen and smaller output of carbon dioxide. The importance of these factors is seen in the flyer.

Birley (3) calls attention to the fact that flying at high altitudes entails bodily reactions comparable to those of muscular exertion at sea level, the object being to provide oxygen in sufficient quantity for the bodily needs. He states that the British found that those individuals who were used to taking vigorous exercise resisted the effects of altitude better than others. He calls attention to the fact that the individual whose central nervous control is either not developed or is weakened as a result of fatigue is utterly unsuited for high altitude work. He states that the shallow breather has

inadequate ventilation and has already anoxemia by reason of the breathing, while an individual whose pulse and blood pressure are abnormally sensitive to exertion or excitement has no reserve to fall back on. He considers that a person suffering from effort syndrome is in much the same physical state as a healthy pilot at 20,000 feet.

Bainbridge (2) states that exercise appears to be beneficial mainly as it stimulates the metabolic activity of the tissues thereby promoting their functional efficiency. That exercise improves the physical condition of the flyer has been demonstrated by Scott (17). He considers that good physical condition contributes to good mental alertness, good health and high morale. He found flyers at his station in poor physical condition. He had them given daily exercise for one hour. In a month he noted an increase in their physical condition, higher morale and less complaining of petty ailments. The physical efficiency, as measured by Schneider's circulatory efficiency test showed that before exercise was begun, 20 per cent showed an index of 14 or above, 60 per cent showed an index of 8 to 13 and 20 per cent showed an index of 7 or less. At the end of the month of daily exercise, 80 per cent showed an index of 14 or above, 10 per cent an index of 8 to 13 and 10 per cent an index of 7 or less.

He considers that mass athletics are far better than competitive athletics in that moderation in exercise is the aim. He considers that setting up exercises are too formal and lack the zest of games. He recommends volley ball, tennis, equitation, swimming or golf. He states that volley ball is particularly valuable because it exercises neuro-muscular coördination so necessary to the flyer. He concludes that although exercise is the main factor in physical fitness, it alone will not keep a man in good physical condition. Other factors to be considered are loss of sleep, constipation, excesses, fatigue effects and cross country flights.

During the war, considerable attention was paid in this country to the physical condition of the flyer and physical directors were assigned to the various flying fields to superintend the exercise and physical condition of the flyers and particularly the student at training schools. Mass athletics were considered most desirable. The report in the Air Service Medical states "Flying as a feat requiring mental and muscular coördination is best found in athletes in prime physical condition and also in those who have developed

a sense of alertness." A gymnasium and an athletic field are considered essential adjuncts of any flying field.

TEST FOR PHYSICAL FITNESS

Various tests for physical fitness have been described by a number of workers and as the flight surgeon is interested in having a test available, a brief consideration will be given to some of the more important ones.

Schneider's circulatory efficiency test (19) has already been described in the first chapter. This test has been used very largely in the United States Air Service and has given satisfaction. The English tests, which are used jointly to determine the reaction to altitude, nervous stability and physical fitness, have been for the most part described in Chapters V and X. The two which have not been described are the test of the response of the pulse to exercise and the examination of blood pressure. These tests are as follows (14).

Response of the pulse to exercise. The pulse rate is taken sitting and the total number of beats in sixty seconds recorded. If the pulse is unsteady it should be counted in periods of five seconds until the minimum constant rate is obtained. The subject is then directed to stand up, and the number of beats during the first five seconds (e.g., 7) is recorded at the rate each minute (e.g., 84). With the subject still standing, the examiner now records the lowest steady rate to which the pulse falls. (A pulse which greatly increases in rapidity on standing and takes a relatively long time, e.g., one to two minutes, to return to its lowest steady rate indicates a poor splanchnic vasomotor control; in such cases the pulse maintains its quicker rate during standing.) If the pulse is, for instance, 84 on standing up, and settles to a steady 72 after 50 seconds, record as 84 to 72.

The regulated exercise is then carried out as follows: Placing and keeping one foot upon a chair, the subject stands alternately upon the chair and the floor five times in fifteen seconds, the speed being regulated by the examiner raising and lowering the subject's wrist in every three seconds. At the end of the fifteen seconds, the time which it requires to fall to its steady rate is recorded, in addition to the rate per minute in the first five seconds after exercise. In good health the increase of rate is 12 to 24, and the time of return to normal fifteen to twenty-five seconds. If the time of return exceeds thirty seconds it is suggestive of cardio-vascular insufficiency, or nervous instability; an example of a healthy pulse therefore is as follows: Sitting, 72; standing, 84 to 72; after exercise, 96; time of return to normal standing rate, twenty seconds.

The systolic and diastolic pressures should be recorded by means of the sphygmomanometer, the difference between them indicating the "pulse pres-

sure." In a good subject the "pulse pressure" is about 25 to 40 mm. Hg. A difference in pressure of 50 or over when combined with a diastolic pressure below 70 is unsatisfactory. Allowance, however, must be made for nervous excitement which frequently causes a raised systolic pressure, e.g., 140 to 150 mm. Hg instead of the normal 115 to 120 mm. Hg. Readings should be taken more than once as the first may be unduly high from nervousness.

These tests are not to be considered by themselves but in connection with the other English tests already described and the opinion drawn should be based upon the reaction of the subject to the tests as a whole. Schneider's (22) opinion is that the English tests require too much voluntary attention and hearty coöperation on the part of the subject and that the results are not capable of physiological interpretation unless they represent the best the subject can put into each test.

Martin (13) has described a muscle strength test. Of the forty muscle groups he selected five pairs to be used as samples. The five pairs selected are the pectorals, wrist flexors, fore-arm flexors, thigh adductors and thigh abductors. There is a spring balance to which a loop is attached. The loop is adjusted around the arm or leg. After the loop is adjusted, the subject contracts with all his power the muscle group to be tested and simultaneously the operator pulls on the spring balance. When the resistance of the subject is overcome the pull is discontinued, the scale on the balance is read and the number noted. Care must be taken not to jerk the balance and to discontinue pulling as soon as the muscles yield. The strength of the individual is calculated from the strength of the muscle groups. He adds the strength of these groups as represented by pounds pull on the balance and multiplies this total by 5.65 in the case of men and 5.55 in the case of women. The total strength in normal men ranges from 3000 to 5000 and in women less than 3000.

It is essential that the subject coöperate fully in this test and before it can be used as a measure of fatigue a normal must be established for each individual.

Sargent (16) has described a number of strength tests. In one, called the jump test, the subject adjusts a disk to the level of the top of his head in a normal standing position. He flexes his ankles, knees, hips and arms. Striking the disk with his head he projects himself as high as possible. This is supposed to call forth the exertion of full muscle capacity. Knack is important yet in a large

group one gets a fair estimate of the physical capacity. The formula of the test is as follows:

$$\frac{\text{Weight in pounds} \times \text{height of jump}}{\text{Height of person}}$$

A good individual gets a rating of 38 or more.

Dreyer's (6) test for physical fitness is as follows: Stem height is determined, the subject seated with the os sacrum against a support pushed against a corner, knees flexed, head straight forward. Chest circumference is measured over the skin at the nipple line during normal breathing. Vital capacity is measured, this being the amount of air the subject can expel from the lungs after the deepest possible inspiration. Then the weight stripped is taken. Dreyer has found constants between weight and vital capacity, between stem height and vital capacity and between chest circumference and vital capacity. From these he has calculated tables which give the theoretical weight, vital capacity and chest circumference. From these tables the per cent of variation between the actual and the calculated measurements can be determined.

Crampton (4) has devised a test for rating physical fitness which is on a percentage basis. The pulse rate and systolic blood pressure are taken in both reclining and standing positions. He claims that in proportion as the systolic compensation takes place on standing, the heart is spared from speeding up, and vice versa, in the ratio of two beats to 1 mm. blood pressure. A 10 mm. rise in systolic pressure and a rise of eight beats in pulse rate were taken as normal. A final percentage of 60 to 100 is normal. A rating below 50 calls for investigation. Exercise effects are not taken into consideration in this test.

Scott (18) studied aviators by means of both Crampton's and Schneider's tests. In 200 cases he found that there was a fairly clear line of men qualified and disqualified for flying with Schneider's test. He found it was possible to show with a fair degree of accuracy that those who make a score of eight or more will be qualified and those with a score of seven or less will be disqualified. With Crampton's test there was no clear line of demarcation. He believes the difference is due to the fact that Schneider takes into consideration a pulse rate after exercise and the length of time for the pulse to return to the normal standing rate while Crampton does not.

Scott found that with the Schneider Index of 7 or less, that the

neuro-psychiatrist would find at least three of the following symptoms; increased psycho-motor tension, prolonged secondary dilatation of the pupils, relaxed peripheral circulation, ties and tremors. It was Scott's opinion that the test does not supplant but should be used in conjunction with a thorough physical examination. He also believes that that is the best test so far for the measurement of physical fitness and fatigue in the aviator. He found that flying fatigue, loss of sleep, lack of exercise, excesses and acute infections all lowered the score. Bradycardia gives a better rating than the condition warrants on account of the low pulse rate.

Schneider (20) believes that too much is demanded of efficiency tests; that the maximum effort that can be tolerated can be determined and that poor adjustments can be detected but that more than that they cannot do.

SUMMARY

Flying, then, causes, by means of its strain and stress, fatigue. Fatigue is apt to become chronic and develop into that condition known as staleness, effort syndrome or neuro-circulatory asthenia. This condition results in a flagging of physical efficiency, falling off in flying ability and a development of nervous instability. These may lead to serious accidents unless the individual is relieved from flying. It is the duty of the flight surgeon to detect these conditions in their incipency, in order that accidents may be prevented and the individual restored at an early date to his former condition.

This condition may be prevented, by elimination of the neurological type by careful selection examination, by insistence upon regular exercise, preferably volley ball, tennis, golf, swimming or equitation. If this condition develops and does not respond to exercise treatment, the subject should be given sick leave and sent away from the vicinity of the flying field.

The condition of fatigue is similar to that of oxygen want. Physical fitness improves the ability to compensate to oxygen want. Physical fitness is more important in the aviator than in any other walk of life. The flyer should be under constant supervision of the medical officer trained in the subject of physical exercise and physical fitness.

As a routine test, it is believed that Schneider's circulatory efficiency test is best adapted for the use of the flight surgeon, bearing in mind the factors that influence this test as outlined in the first chapter.

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CHAPTER XIII

PROTECTIVE DEVICES

There are a number of devices by which the efficiency of the aviator may be improved which are of interest from a medical standpoint. Those which we will consider in this chapter are oxygen supply apparatuses, goggles, ear plugs and clothing.

OXYGEN SUPPLY APPARATUSES

We have seen how serious are the effects of high altitude on the aviator. That the use of oxygen is essential has already been indicated in a previous chapter. It has been said that no man can do efficient work above 18,000 to 20,000 feet without oxygen and it has already been said that repeated flights above 12,000 feet are less fatiguing if oxygen is taken. A supply of oxygen by artificial means increases the percentage of oxygen in the air breathed and thereby increases its partial pressure which, as we have seen, is the important factor. We shall first discuss the methods available of supplying oxygen and then discuss these methods in more detail.

The earliest attempt to supply oxygen to the aviator was by means of a steel tank of oxygen under pressure. A valve for reducing this pressure was attached to the tank and a length of tubing connected this valve to the oxygen mask. The aviator regulated it by the amount he turned the valve. It was, of course, wholly dependent on the aviator and was a matter of guess work. It was soon seen that it would be necessary to develop an instrument which would deliver the oxygen in a more satisfactory manner.

Obear (1) states that the general specifications to which an efficient oxygen supply apparatus should conform are:

(1) The apparatus at any given altitude should deliver automatically to the aviator sufficient oxygen to supply the deficit at that altitude. This is equivalent to bringing the aviator back to sea level physiologically. (2) At all times the aviator should be able to determine the amount of reserve oxygen. (3) The aviator should have some visible evidence that the oxygen is flowing freely. (4) The instrument should be as small in volume and weight as possible.

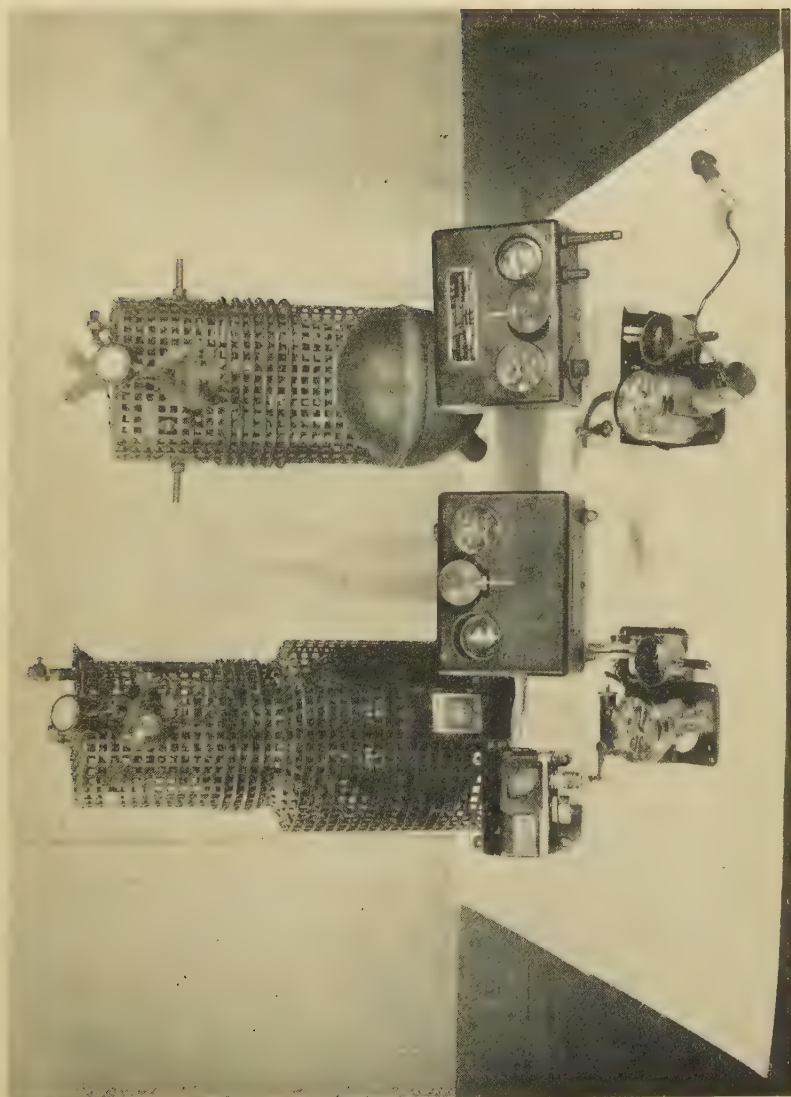


FIG. 26. OXYGEN SUPPLY APPARATUSES, BOTH GAS AND LIQUID

There are two ways in which we can meet this problem. One is by means of a gas oxygen apparatus and the other is by means of a liquid oxygen apparatus.

GAS APPARATUSES

There are two physical methods by which we can solve the problem of a satisfactory gas apparatus. In both we have to start with a steel tank of oxygen under pressure. Connected with this is an instrument which reduces the pressure of oxygen and delivers the oxygen automatically to the aviator proportionate to the altitude. This may be solved according to Obear by having an apparatus which functions by means of a constant static pressure operating against a variable orifice; or we may have an apparatus operating on the principle of a variable static pressure and a constant orifice.

One of the earliest instruments was that devised by Dreyer. This instrument is based on the principle of a constant static pressure and a variable orifice. Inasmuch as this instrument is but little used now, it does not seem worth while to describe it.

Later on Dreyer assisted the United States to devise a new instrument which became known as the United States Dreyer. This instrument is still being used to some extent. The parts of the instrument are assembled on a metal base and are as follows: The reducing valve, surmounted by a high pressure oxygen gauge, a manual control valve, a distributing valve which is connected with an aneroid and a flow indicator. The oxygen tank is connected by means of a length of pressure tubing to the reducing valve. The oxygen passes from the tank through this reducing valve. There is a by-pass which allows the oxygen to register on the high pressure oxygen gauge. The gas, however, does not pass through this gauge. The gauge is calibrated in two scales, one shows the atmospheres of pressure and the other the percentage of oxygen reserve. The aviator can thus tell by glancing at this gauge, the approximate amount of oxygen still available. The reducing valve is divided into two chambers. The upper is separated from the lower by means of a German silver diaphragm. This contains atmospheric air hermetically sealed. Connected with the center of this German silver diaphragm, is a lever which works about a fulcrum in the base of the valve. There is a valve seat above the inlet of the chamber. The lever moves the diaphragm and the diaphragm operates the valve seat in such a way that the oxygen, which in the full tank is

under a pressure of 150 atmospheres, is reduced to a pressure roughly of one-half to one atmosphere.

There is one serious fault in this arrangement and this is that low temperature causes the volume of atmospheric air in the upper chamber to decrease. As it decreases, the German silver diaphragm bulges upward and this tends to close the opening and restrict the flow of oxygen. As a result less gas passes through. The oxygen being reduced in the reducing valve then passes through a length of pressure tubing to the manual control valve. The manual control valve is marked "off," "one man," and "two men." By turning this valve the amount of oxygen may be increased or decreased as indicated. By means of another length of pressure tubing the gas passes to the distributing or reducing valve. The distributing valve consists of a cylinder and piston. There is an inlet at one end of the cylinder and an outlet at the other. There is a groove of varying depth on the surface of the piston and a passage leads from this groove to one end. As the piston moves back and forth in front of the outlet end of the cylinder, the area of the outlet changes. Connected with the cylinder is an aneroid. The expansion and contraction of the aneroid causes the piston to move back and forth, thus varying the flow of oxygen proportionate to the altitude. By means of another length of pressure tubing the oxygen passes from the distributing valve to the flow indicator. This is a chamber in which there is mounted a small German silver fan. The flow of oxygen causes the fan to rotate. By watching this fan, the aviator can see whether or not the apparatus is functioning and get a rough idea of the amount, because the greater the flow, the more rapidly the fan rotates. From the flow indicator the gas passes to a two-way outlet. A tube is attached to each side of this outlet and the oxygen passes to the oxygen masks of the two aviators.

The United States Dreyer not proving wholly satisfactory a later instrument was developed known as the Clark. This is of the same general type as the Dreyer but there are a number of improvements. The high pressure gauge is smaller than that of the Dreyer but is calibrated to a higher pressure. The reducing valve has a different arrangement than is the case in the Dreyer which prevents the functioning of the valve being reduced at low temperatures. The normal position of the reducing valve is open, which is an advantage in case the valve becomes frozen. The arrangement in the manual

control valve is different but is superior to that in the Dreyer. Between the reducing valve and the manual control valve is a full flow attachment; in case anything goes wrong with the manual control or regulating valve, the full flow attachment may be opened and the oxygen will be sidetracked directly from the reducing valve

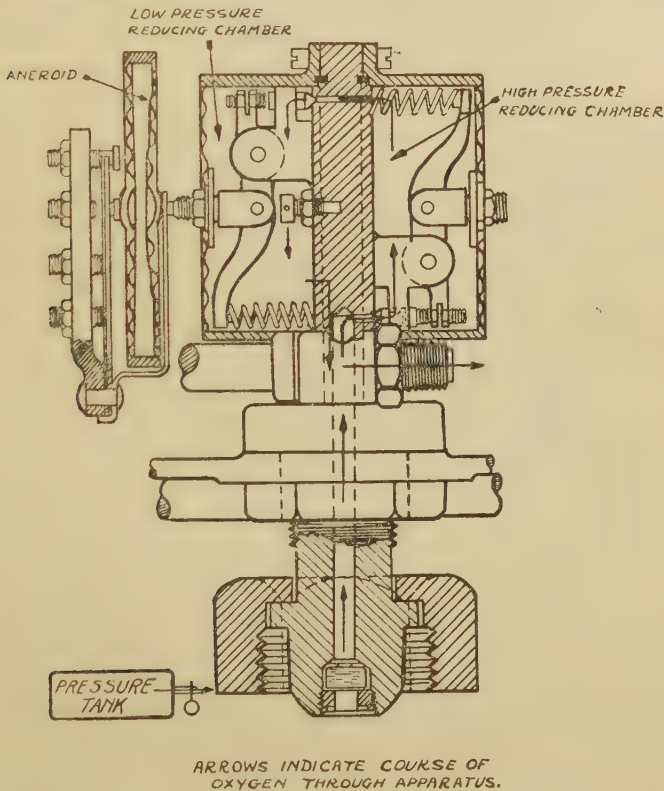


FIG. 27. DIAGRAM OF PROUTY OXYGEN APPARATUS

to the aviator. There is a filter area composed of several fine mesh copper wire disks at the entrance to the reducing valve which takes out the water vapor and dust. The connection of the aneroid with the regulating valve is different than in the Dreyer and in case a leak develops in the aneroid the valve will open and the flow of oxygen be increased instead of decreased. The flow indicator is more sensitive than the one in the Dreyer. The Clark operates on the principle of constant static pressure and variable orifice.

The third type which has been developed in the United States is the Prouty. This instrument is essentially different from those already described. This instrument operates on the principle of variable pressure and a constant orifice. The apparatus is very much smaller and lighter and its working quite different from the others. The gas enters the apparatus through a filter to the high pressure reducing valve. In this chamber the gas is reduced from 150 atmospheres pressure to approximately 50 atmospheres pressure. One end of the chamber consists of a flexible German silver diaphragm. As the gas enters the diaphragm expands outward thus causing the spring to close the inlet and stop further inflow. It passes from the high pressure chamber to the low pressure reducing chamber. Here the gas is further reduced from 50 atmospheres pressure to one-half to one atmosphere pressure. The low pressure valve is constructed and operates similarly to the high pressure valve except that it has in addition an aneroid attached to it. The expansion of the aneroid has no effect until an altitude of 3000 feet is reached. When this point is reached, the aneroid's expansion causes the low pressure diaphragm to be affected. The low pressure valve then opens and the gas enters from the high pressure to the low pressure valve. The outflow is determined by the difference in static pressure on the outside of the valve and the inside of the valve. As the pressure is reduced more gas collects in the chamber and it again flows out. A series of wavelike movements occur which result in a fairly constant flow of oxygen.

The high pressure gauge is calibrated in atmospheres of pressure and percentage of oxygen supply. The flow meter is a pressure indicator. A certain flow means a certain static pressure. This pressure is transmitted to the pointer and the pointer indicates whether or not sufficient gas is flowing to supply one man or two men at different altitudes. The dial on the scale is divided into three segments, each segment representing 10,000 feet of altitude. There is a dial for the one man flow and for the two man flow. There are two outlets one of which may be closed in case one man desires to use the instrument. The Prouty instrument has advantage in that it is less complicated, it is lighter and takes up much less space.

It is customary in using gas oxygen apparatuses to carry two pony cylinders of oxygen gas, each containing 500 liters of gas under pressure. This increases the weight and space necessary to carry oxygen on high altitude flights.

LIQUID OXYGEN

Liquid oxygen was first used during the war by the Germans. The apparatus now in use and upon which others have been modeled is the Ahrendt and Heylandt type. A description of this apparatus has been made by Obear (2). The apparatus is constructed something on the principle of the thermos bottle. There is a spherical

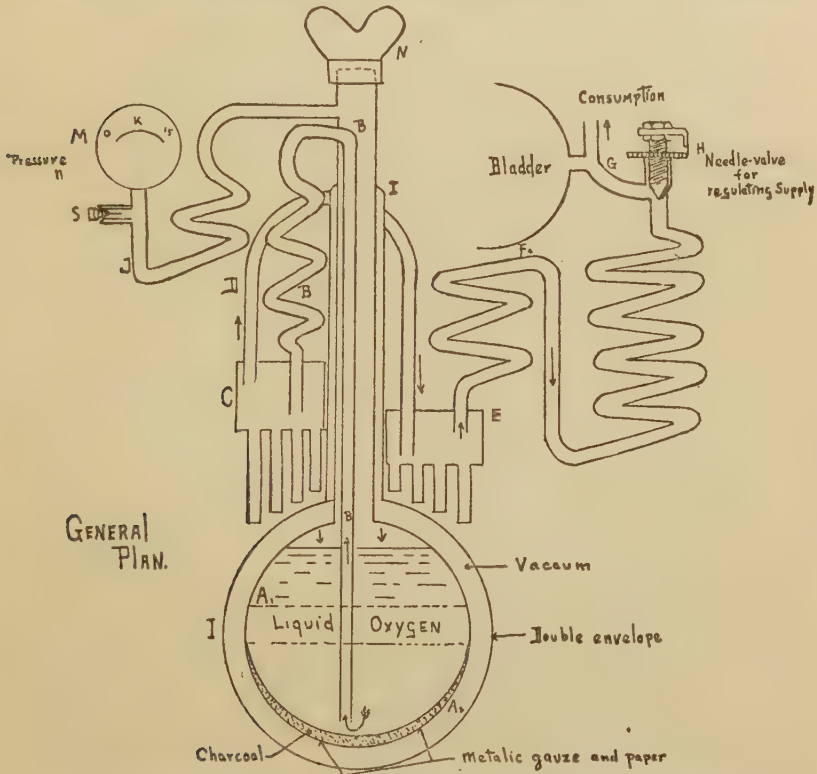


FIG. 28. SCHEMATIC REPRESENTATION OF THE GERMAN LIQUID OXYGEN APPARATUS

vessel of two layers of metal separated by a vacuum. The liquid oxygen is stored in this vessel. It tends to vaporize and the pressure of this vapor forces the liquid up through a fine tube to an evaporating chamber. This evaporating chamber consists of a chamber proper with several fingerlike blind tubes connected with it. The oxygen is forced up into this chamber where it is warmed,

tends to vaporize and is allowed room for expansion. From this chamber it passes to another vaporizing chamber of like construction where it becomes further warmed and further vaporized. From this chamber it passes through a long coil of tubing to a triple outlet controlled by a manual control valve. In this final coil of tubing, the oxygen, now thoroughly vaporized, becomes sufficiently warmed to be breathed. The manual control valve can be set for one man, two men, or in some of the instruments the valve is registered in liters of oxygen delivered. The three-way outlet is for two tubes, one leading to each of two aviators and the third for a breathing bag of rubberized fabric which acts partly as a storage bag and partly to keep the flow of oxygen constant. Connected with the neck of the vessel is a pressure gauge and a safety valve. The pressure gauge registers the pressure of the vaporized oxygen which is above the liquid oxygen. If the apparatus is not in use the pressure of the vaporizing oxygen may become too great and danger of explosion result, hence the need of the safety valve to relieve such pressure.

Between the two layers of the vessel is a cup of charcoal in the earlier models and of calx in the later models. This is to absorb the moisture and air which may escape into the vacuum and therefore keeps the vacuum more perfect. The instrument operates by vaporization. The heat necessary to vaporize the oxygen is obtained from the surrounding atmosphere. The boiling point of liquid oxygen is -185°C . Therefore, even though the surrounding atmosphere may be very cold it will still be hot compared to the boiling point of liquid oxygen.

The advantages of the liquid oxygen apparatus may be summarized as follows. The weight of the complete apparatus is only about one fifth of the complete unit necessary for the two-man outfit of the gas type. The pressure is less, thus less danger of leakage. It is less complicated and thus less apt to get out of order. If pure liquid oxygen be used, the gas capacity is about 1800 liters as against 1000 liters of the two-man outfit of the gas type. Obear (2) claims that as a disadvantage the supply of oxygen diminishes as the altitude increases. The Germans claim that this defect has been obviated, though it is not known just how. Other disadvantages are the necessity of having a special plant at the air base for the manufacture of liquid oxygen, and that specially designed vessels are needed to transport liquid oxygen. Another disadvantage is that there is considerable wasting of oxygen.

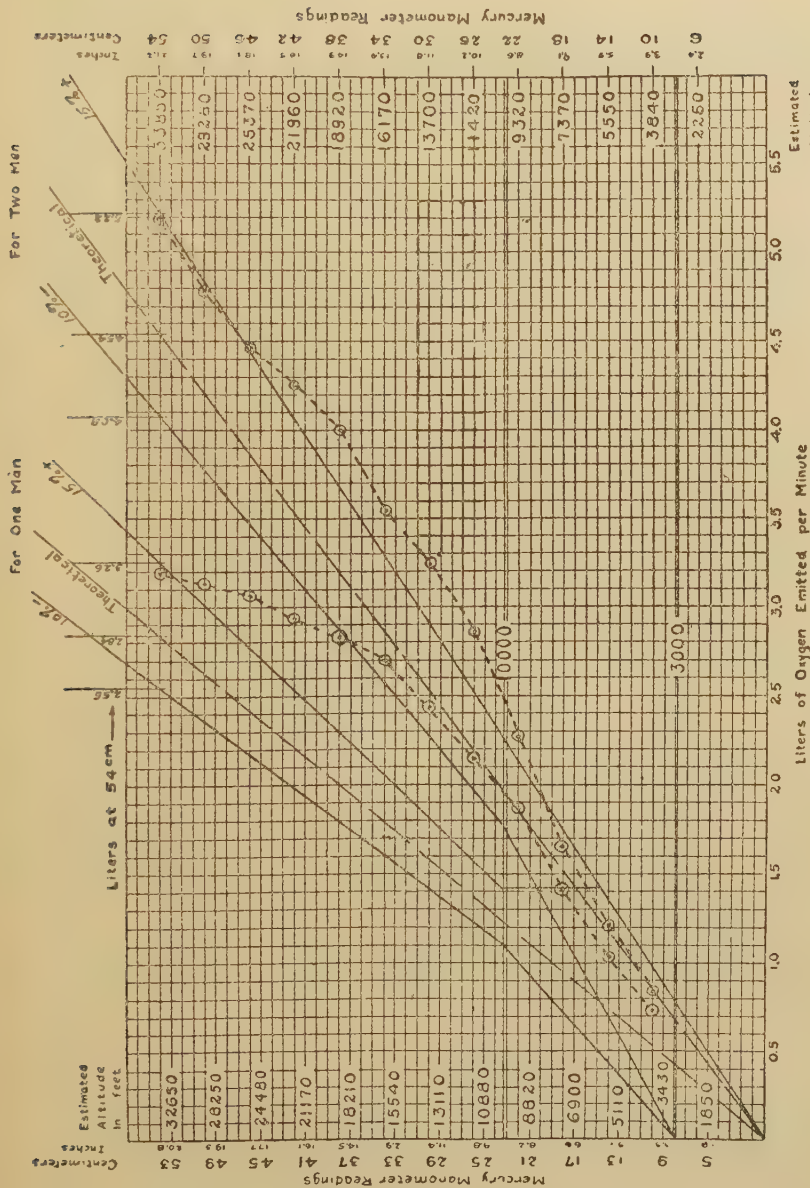


FIG. 29. TOLERANCES AND THEORETICAL CURVES FOR FLOW OF OXYGEN THROUGH DREYER OXYGEN APPARATUS

The Germans have also devised an apparatus similar to this in which fifteen liters of liquid oxygen are carried, having a total gas capacity of 12,000 liters of gas. This is sufficient to supply from eight to ten passengers for about five hours.

After selecting our apparatus it is necessary to know whether or not it is functioning properly. It is therefore necessary to put it through a series of tests. One test is by the bell-jar, which is in reality a small low-pressure chamber. A refrigerating coil can be connected with it so that the effect of cold can also be determined on the functioning of the apparatus. By means of the bell-jar test we can find the effects of temperature, vibration and position. It can also be tested in a low pressure chamber and finally, in actual flight. The flow of oxygen is collected, measured and compared with the theoretical flow. There are tolerance curves which represent a flow 10 per cent less than the theoretical flow and 15 per cent above the theoretical flow. The actual flow of oxygen should lie between the two tolerance curves, to be satisfactory.

It is essential that the oxygen used be pure and free from moisture. It is found that even 0.10 per cent moisture is sufficient to cause clogging of the oxygen line at temperatures as low as are reached in altitude work. The oxygen tank should be inspected and cleaned whenever necessary. A good method of cleaning the oxygen tank is as follows, when it has been found to be corroded and covered with scale. Treat with benzol and follow with a strong caustic solution, then immerse for considerable time in commercial sulphuric acid, then dry with hot compressed air. When the bottles are empty they should be kept stoppered to prevent the accumulation of moisture. Moisture can be removed from oxygen by passing it through phosphorous pentoxide.

It is desirable that the oxygen tanks be placed inside the fuselage to prevent undue chilling, as cold oxygen is very unpleasant to breathe.

AMOUNT OF OXYGEN REQUIRED

The question arises as to how much oxygen must be supplied to the individual. The formula used by the United States Air Service is as follows: $O = 4 - \frac{4P}{760}$ where O = Flow of oxygen in liters per minute at 20°C. and 760 mm. pressure; P = atmospheric pressure in millimeters. If two men are being served from the same

regulator, the above amount is increased 60 per cent. This, however, seems to be insufficient as there are several factors which should be taken into consideration. The following figures were worked out by Mr. R. W. Clarke of the School of Aviation Medicine.

Chart Showing

A—The per cent of oxygen needed at various altitudes to insure a partial pressure of oxygen of 160mm of mercury.

B The per cent of the respired air which must be pure oxygen from the supply tank to insure the above.

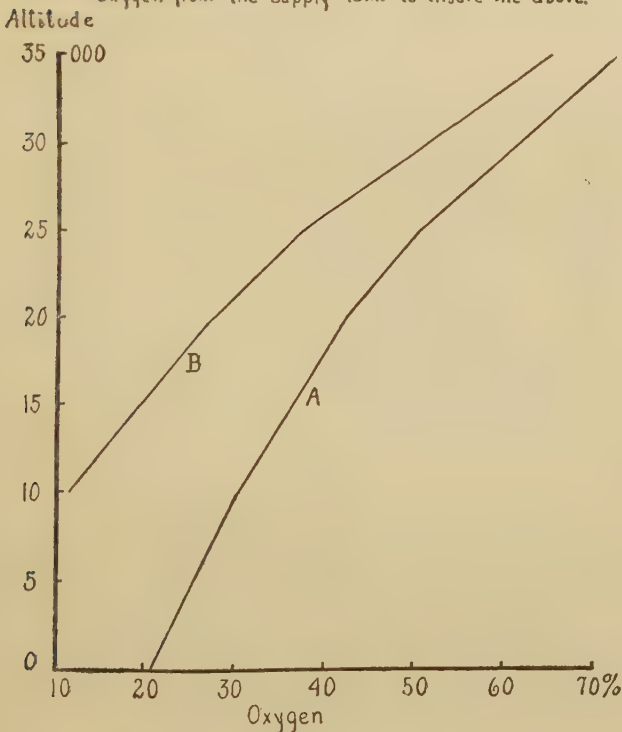


FIG. 30

In considering the amount of oxygen needed by an aviator at high altitudes the following factors must be considered: The barometric pressure, the oxygen requirements of the flyer, which in turn depend on his activity, the temperature, etc., and the efficiency of administration. These will be considered in order.

It is desired to supply enough oxygen to the pilot to insure his having, if possible, the same amount available as at sea level, thus eliminating the effect of the reduced pressure. This must be done by increasing the per cent of oxygen in the inspired air in such proportion that the partial pressure of oxygen will not be less than that at sea level, viz., 160 mm. of mercury. Table 2 gives these values. (See Fig. 30.)

Since air containing these amounts of oxygen is always produced by adding pure oxygen to the atmospheric air, it would be convenient to know how much oxygen must be added to increase the

TABLE 2

ALTITUDE	BAROMETRIC PRESSURE	O ₂ PER CENT NEEDED
0	760	21.0
10,000	530	30.2
15,000	440	36.4
20,000	375	42.7
25,000	315	50.8
30,000	260	61.6
35,000	220	72.8

normal 21 per cent to that desired at any altitude. This relation is given by the following formula:

$$X = \frac{N - 0.21}{0.79}$$

where X = the fraction (per cent $\div$ 100) of the inspired air which must be pure oxygen from the source of supply in order that the mixture will have an n th part (per cent $\div$ 100) of oxygen as it enters the flyer's lungs. Thus at 15,000 feet an atmosphere of 36.4 per cent oxygen, will give the desired 160 mm. oxygen pressure. Therefore

$$X = \frac{0.364 - 0.21}{0.79} = \frac{0.154}{0.79} = 0.195$$

hence of the air breathed, 19.5 per cent must be added from the pure oxygen supply.

It is next necessary to consider the requirements of the flyer before the amount of oxygen with which he must be supplied can be determined. Since we have determined above the composition of the air necessary for his optimum maintenance, it is only necessary to

examine some facts regarding the amount of air needed, that is, the minute volume of pulmonary ventilation. In a series of experiments with a bicycle ergometer, the following values of minute ventilation under varying circumstances were obtained, all at sea level.

Rest, sitting on bicycle, back unsupported.	8.21 l. (20 experiments)
Pedalling 70 R.P.M., without brake.....	14.30 l. (3 experiments)
Pedalling work equivalent 2000 foot pounds per minute.....	21.60 l. (6 experiments)
Pedalling work equivalent 4000 foot pounds per minute.....	37.82 l. (15 experiments)

It is believed that the work at the last rate is more than would ever be encountered in an airplane, even in the most severe conditions, excepting possibly in combat engagements. It is therefore not improbable that the range of 10 to 20 liters per minute will include all the cases where an oxygen supply must be provided. An examination of the appended chart shows that this supply varies over a range of from 2.4 to 26 liters per minute, and from 13 to 26 liters per minute at a single altitude, 35,000 feet. This will serve to emphasize the possible importance of the activity of the flyer in its relation to his needs, and indicate the desirability of experimental determination of the ventilation rate under actual flying conditions.

The third factor is, in practice, of as great importance as the first two, since if the oxygen supply does not actually reach the lungs of the flyer, it is useless. And in the ordinary type of oxygen helmet there is a very excellent opportunity for wastage of oxygen. In the first place, inspiration occupies not more than half the time of the respiratory cycle, and the oxygen is being swept out by the expired air, or in the pause at the end of expiration it may collect in the mask. In this case the oxygen is swept into the lung with the next inspiration, but as the mask has very little space to be thus filled, and the time for filling is very short, the amount of oxygen conserved in this way is probably negligible. We may conclude, therefore, that about half of the oxygen must be wasted, unless some valved mask to separate the inspired air is used, and to compensate this loss the calculated amount of oxygen needed per minute must be doubled.

After the oxygen is supplied in a steady stream it will be seen that nearly half will be wasted and the aviator does not get what is

supplied. Individually the amount of oxygen needed varies with the ventilation rate as shown in the chart.

From the study in physiology it will be seen that not only is oxygen essential for one flying at such altitudes but that the individual himself must not be the one to decide when it is necessary. The effects of oxygen want being insidious, the oxygen supply must

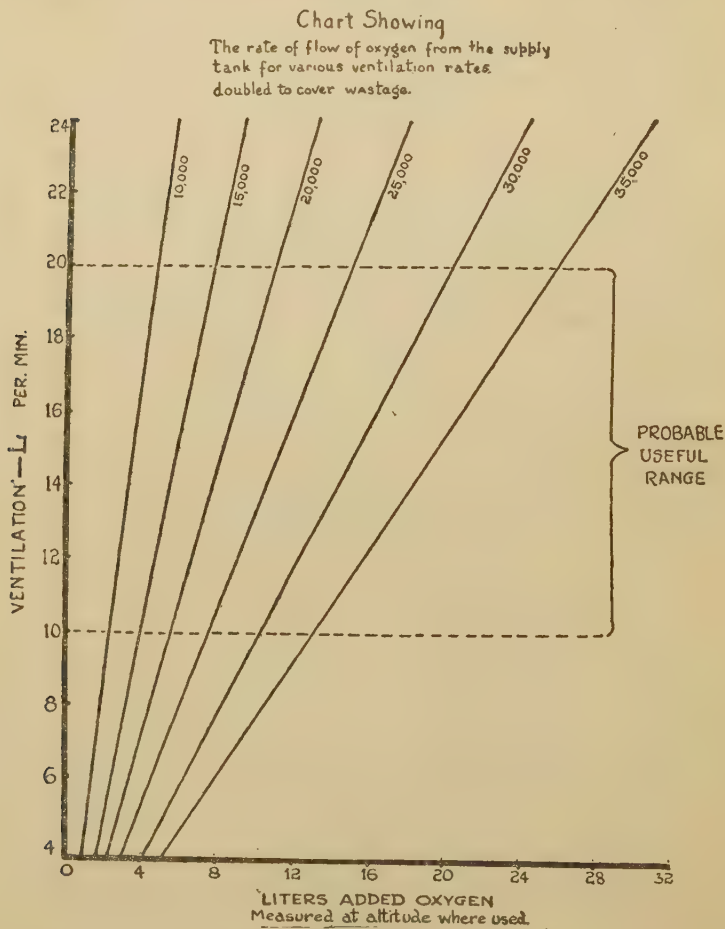


FIG. 31

be automatic according to the needs of the pilot. Pilots and observers should be required to use oxygen on any flight above 18,000 feet and where altitude work is being performed over prolonged periods and repeatedly at heights above 12,000 to 14,000 feet it should also be required.



FIG. 32. THREE TYPES OF GOGGLES

MASKS

With whatever instrument is used there must be a suitable oxygen mask which is fastened over the nose and mouth, permits free flow to the nose and mouth and free expiration. It must be light and comfortable and not interfere with vision. The usual mask is made of rubber covered with fabric of a size sufficient to cover the nose, mouth and chin. The margins are lined with fur. There is an inlet for the oxygen tube opposite the nose and mouth and an outlet for the expiration above the nose and opposite the mouth, each covered by rubber valves. It is fastened around the head by rubber bands. It is important that the mask should not in any way obstruct breathing and before any mask is adopted it should be thoroughly tested out at sea level to find out if there is any resistance to breathing. The breathing of oxygen through a tube and mouthpiece is not satisfactory in that it means wastage of oxygen and a lower concentration of oxygen in the inspired air.

GOGGLES

The next protective device to be considered is that of goggles. A satisfactory goggle is of the most importance and most difficult to obtain. Various devices have been used for the production of goggles.

The ideal requirements for any goggle are (1) no limitation of the field of vision, (2) no distortion of vision, (3) a proper fitting to prevent leaks, (4) comfort, (5) elimination of materials apt to cause injury in case of crash.

During the world war various substitutes for optical glass were used in order to prevent danger to the face and eyes in case of accident. Celluloid, non-breakable glass and glass in two layers cemented by a layer of gelatine or other adhesive substance were all used. Celluloid and gelatine interfere with the transmission of light and cause distortion of the rays of light. Celluloid likewise deteriorates very rapidly. Goggles made of two layers of glass with a third cementing layer of gelatine or other substance can be made only in a flat lens and are, therefore, bound to obstruct the field of vision to a certain extent.

The tendency now is to use optical glass. A curved lens is made sufficient size to prevent any interference with the field of vision. Such a lens must be made of optical glass and must not have any refractive error nor cause any obstruction in the field of vision.

It is useless to require pilots to have normal vision and then require them to wear lenses which decrease their vision and cause a distortion in the field of vision. It is believed that a lens which has no refractive power greater than ± 0.12 of a diopter is satisfactory provided that the lenses in the two eyes are of equal strength. The lenses should be removable and may be fitted in a metal frame, each rim being covered with a cushion of pneumatic or soft sponge rubber. The soft sponge rubber is far preferable to the pneumatic rubber because it offers a greater bearing surface, can be adjusted with greater comfort and will obviate leaks. Some pilots prefer a cushion of fur or chenille but it is believed that the sponge rubber is more satisfactory.

An adjustable nose-piece is advisable because of the varying interpupillary distances that are found in different individuals.

There should be a method of indirect ventilation to prevent blurring and frosting of the lenses. The elastic strap which holds the goggles in place should not be adjusted too tightly as it will cause discomfort and even pain.

Above all, it is important that the goggles should not leak. The point at which they are most apt to leak is near the inner canthus of the eye. A leaky goggle is an abomination to the pilot. It causes lachrymation, eventually conjunctivitis and sometimes, in aggravated cases, the development of pterygia. The flight surgeon should make it a point that each aviator is properly fitted with satisfactory goggles.

The danger of the metal frame or of the splintering of the glass can be, to a large extent, obviated if the flyer is instructed to pull off his goggles at crucial moments.

The question of tint in the lens of the goggles is one which may be left to the individual preference of the pilot. Most pilots prefer an untinted lens, as they claim that a tinted lens not only interferes with the transmission of light but that it changes the aspect of the landscape so that certain objects are difficult to recognize and the color of the ground so changed as to render its character difficult to determine in case of a forced landing. In the tropics a tinted goggle is almost a necessity because of the intense glare. Glare conjunctivitis will not be infrequent unless a tinted goggle is used in flying in the tropics. The most satisfactory tints are a very pale green or pale amber.

EAR PLUGS

The constant roar of a high powered motor causes diminution of hearing. The pilot who has no protective device in his ear after a prolonged flight will invariably be markedly deaf. This deafness gradually wears off after a few hours. Constant flying without protection results in a permanent impairment in hearing. A large proportion of the flyers in the United States Air Service show diminished hearing. This deafness can be prevented by using a suitable device. Many flyers use cotton. This is unsatisfactory in that it is irritating and a supply is not always available. If cotton be used, a pledget should be placed in the external auditory canal and a pad over the external ear, the ear-laps of the helmet holding it in place.

Tefft and Stark (4) describe an ear plug composed of parresine and beeswax. These plugs were molded and the aviator warmed them in his hand or near a fire until they became malleable. These were then inserted in the auditory canal. They are very satisfactory but the objections to them are that they can be used but once, are apt not to be handy and they are a nuisance in cold weather because of the difficulty of warming them sufficiently to make them malleable.

A simple and very satisfactory means of protecting the ear is the one used by many aviators and has been described by Scott (3). It consists of sewing a lady's powder puff in each ear-lap of the helmet. The powder puff should be approximately 3 inches in diameter and approximately $\frac{3}{4}$ inch thick. When the helmet is firmly fastened these powder puffs cover the ear satisfactorily and eliminate the excessive roar of the motor.

None of the methods described cut out all sound, nor is it desirable that they should. The pilot desires to hear sufficiently to determine whether or not his motor is functioning properly.

HELMETS

The helmet should preferably be made to order for each individual flyer. It should come low enough on the forehead so that in conjunction with the goggles it will afford protection for the frontal sinuses. It should fit snugly but not so tight as to interfere with circulation. It should fit snugly about the face, otherwise the use of ear plugs or powder puffs will be nullified by the ballooning of

the helmet. The helmet may be made in two weights for winter and summer, the winter one fur lined, the summer one chamois lined. It should be constructed of soft leather and there should be no hard or unyielding substance about it.

CLOTHING

The clothing should be comfortable and allow freedom of movement. There should be no restriction about the neck. The flyer has constantly to turn his head at an extreme angle and a tight fitting collar interferes with this movement, interferes with free breathing and is apt to cause a headache by its constriction. In case of a crash it may actually choke the pilot.

For flying in cold weather adequate protection should be had to prevent chilling or numbing of the extremities. A fur gauntlet or mitten is best for the hands and fur lined moccasins to protect the feet. The flying suit is preferably a one-piece cover-all lined with wool or fur. It should fit loosely and comfortably and should preferably be free from buttons or hooks. It should be provided on the legs, arms and front with a metallic rip or lock-tight arrangement whereby it can be fastened or unfastened in an instant by one quick movement of the hand. This is particularly desirable as the flyer may have to fly over water with the possibility of a forced landing in the water. A heavy flying suit, fastened with buttons can usually be removed only with difficulty and sometimes only with assistance.

In excessively cold weather, the face may be protected by a mask or by smearing it with cold cream or cosmoline. On flights to very high altitude when intense cold is endured, specially devised electrically heated clothing may be used.

Other protective devices in which the medical service is interested are certain mechanical devices which properly lie within the field of the engineering devison. For example, the elimination of as many blind angles as possible in the plane is desirable in order to diminish the restriction of the field of vision. The cowls of the machine should be carefully padded to prevent injury to the head and face in case of a crash. The instrument board should have no metallic substance projecting from the surface of the board. The center of the board should have a pad of leather or felt to protect the head from striking against the instrument board.

When no military reason prevents, the cockpit should be protected by a windshield to keep the wind blast from the propeller from striking against the flyer.

The position of the exhaust should be such that the fumes from it are carried away from the aviators. Otherwise they are apt to inhale considerable carbon monoxide. By means of a Hoolemite carbon monoxide detector, tests were made in the JN₄, the DH₄ and in the Martin Bomber. No trace of CO was found in either pilot's or observer's cockpit.

Parachutes should be worn on all flights where the type of plane does not prevent their use. The parachute should be fitted to the individual flyer as a loose fitting parachute may cause injury when it snaps open.

The life belt should be wide and resilient to prevent damage by sudden shock in a crash. It should be fastened by a clasp that can be opened by one movement of the hand.

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CHAPTER XIV

THE FLIGHT SURGEON

It will be seen from the preceding chapters that the medical officer associated with the Air Service needs a considerable amount of special training. To make the various parts of the selection examination, to carry out the altitude classification test and to superintend the care and maintenance of the flyer from a physical and mental standpoint as well as to understand the effects of the flyer's peculiar environment requires knowledge which the average physician does not have. Consequently when a medical officer is to be assigned to the Air Service, he is required to take a special course of training. In the United States when he has completed his course of training satisfactorily, he is designated as a "flight surgeon."

A flight surgeon should be thoroughly grounded in internal medicine. In addition he must have some knowledge of psychiatry, psychology, physiology, ophthalmology and otology. All are involved in the selection of the flyer. Physiology and psychology are involved in the classification of the flyer. In the care and maintenance of the flyer, physiology and psychiatry as well as general medicine are important. In addition to having special technical knowledge, a flight surgeon must be able to inspire the confidence of those with whom he is associated, particularly in the case of his commanding officer, if he is stationed at a military post, and always in the case of the flyers themselves.

The selection and classification of the flyer is only the beginning of the work for the flight surgeon. His most important work is with reference to the care and maintenance of the flyer. In other words, after having selected and classified the flyers, he must keep them fit to fly from both mental and physical standpoints. To do this he must come to know them intimately, not only from a physical standpoint but from a personal standpoint as well. If he does this, he will soon learn to know which men need careful observation and which men do not. He knows which men take regular exercise and which men are lax in that regard; which men have difficulty in their flying and which men have not. He learns to know their tempera-

ment and who are subject to emotional upsets and who are the steady going type.

The flight surgeon should see a flyer every day because he may recognize some condition which the flyer himself thinks is not important. Minor ailments which are of no importance to a person who remains on the ground, may be of vital importance to the pilot. He should, therefore, meet the flyer, not only at the flying field, but at mess, at quarters and during recreation.

The flight surgeon should keep in close touch with the commanding officer and with the officer in charge of flying, while men who develop difficulties in their flying should be promptly sent to the flight surgeon for examination to determine whether or not the difficulty is a physical or mental one. The cause of an accident or crash should be investigated by the flight surgeon to determine whether or not the cause is a medical one. Whenever the flight surgeon finds a flyer unfit to fly, he either permanently or temporarily prevents his flying until he is again physically qualified. He must remember that his chief *raison d'etre* is to prevent accidents. This he does by eliminating the unfit through careful examinations and by application of his special knowledge of aviation medicine. He is the confidant of the pilot and the adviser of the commanding officer.

The flight surgeon should see that his men keep in fit condition through suitable type and amount of exercise. As pointed out in a previous chapter, flyers are somewhat similar to athletes. While the athlete becomes stale from too much physical work without sufficient recreation, the flyer becomes stale from mental and nervous strain and frequently too little physical work. The flight surgeon must detect staleness in its incipency for, when the staleness becomes marked, recovery becomes slow and sometimes the man fails to recover. It cannot be too strongly impressed upon the flight surgeon that he must keep in close touch with the flyer. It is well known, for example, the famous French flyer, Guynemer, would not have been killed had he been under the observation of a flight surgeon. On the day of his final flight he was physically unfit and had a flight surgeon been available, he would never have allowed him to leave the ground.

The flight surgeon stands in the position of both physician and trainer to the flyer. His duties are quite different from those of a medical officer in any other branch of the service. He is a specialist and he becomes more valuable the longer he is at the work.

The flight surgeon should spend a sufficient length of time in the

air to familiarize himself with the sensations of flying and with the aerial environment. He should fly under all conditions under which the pilot flies; that is, he should make altitude flights, go through acrobatic work, make cross country flights and fly in different types of planes. The flight surgeon gains great insight into the mental adjustments of the pilot on a cross country trip of some duration. The flight surgeon who has made forced landings under various conditions gains a psychological viewpoint on flying which it is impossible to obtain in any other manner. Whether or not it is necessary or advisable for him to become a pilot is a debatable question. As a routine measure it is not believed to be either one. The best flight surgeon is one who is not too young to gain the confidence of the pilots and the commanding officer and as a rule by the time he becomes qualified as a flight surgeon, he is too old to learn to fly. It is advisable that he should have a certain amount of instruction in learning to handle the controls of a ship. While he should not be too young, neither should he be too old to appreciate the viewpoint of youth, as most flyers are youthful.

The flight surgeon can make himself the most valuable officer on the flying field if he applies his responsibilities and opportunities. The civilian flight surgeon is something that has not as yet come into being but as aviation develops, his services will be needed there fully as much as in military aviation.

The flight surgeon must remember that the flyer is not different from any other individual except that he is subject to a changed environment and to certain stresses and strains to which the ground officer is not subject. These changed conditions are prone to cause physical deterioration and degeneration of the mental and nervous systems, unless due care is exercised in supervision. The duties of a flight surgeon in the United States Army are specifically provided in a general order which is quoted below.

Duties of flight surgeons. Medical officers who have had special training and instruction at the authorized school for flight surgeons and who have been reported after such training and instruction as qualified for the duties of flight surgeons, will, when assigned to such duties by proper authority, be considered as specialists charged with the following duties: The flight surgeon will act as adviser to his commanding officer on all matters pertaining to the physical fitness of the flying personnel; he will make recommendation for the relief from flying duty of officers or enlisted men who are found physically or mentally unfit for such duty and will make such recommendations as he deems proper based upon his special knowledge as to the care of the flyer,

physical exercise, recreation and periods of rest; he will take sick call for the flying personnel and recommend disposition of the cases excused from flying duty; he will visit such flying personnel as may be sick in the hospital and consult with the attending medical officer regarding their care and treatment; he will make the special physical examinations required for flying personnel by special regulations of the War Department; he will make such special technical reports as may be required by the Air Service and by the Surgeon General. If junior in rank to the surgeon of the post or station he is the assistant to the former, but should be given freedom of action in all matters pertaining to the physical fitness of the flyers. He will also be given every facility for performing his special duties and for acquiring additional information relative to the medical problems of flying. He should live in as close touch with the flying personnel at his station as is consistent with conditions existing thereat.

The flight surgeon in his examinations for selection cannot be too careful. Especially is it urged upon him to make a thorough neuropsychic examination. Only by such a method can he determine the presence of hereditary or innate nervous taints that result in the development of inefficiency and in the increased frequency of accidents.

Every flyer should be reëxamined once in every six months and after any illness. These are the international medical requirements as well as those of several military forces including that of the United States.

When it comes to the question of a waiver the flight surgeon must consider each case individually. In the applicant for flying training *no waiver should ever be considered*. In the trained pilot, his flying experience may be taken into consideration. Such a man has learned to compensate for his defects. Even here, however, it is not believed that any waiver should ever be considered for deficient depth perception nor for any defect revealed in the neuropsychic examination. Other factors must be considered solely on their importance together with the flying experience of the pilot.

The flight surgeon must look at Aviation Medicine as a branch of preventive medicine. It is his duty to prevent accidents and keep the flying personnel fit for air work at all times. This he does by careful selection examinations, by classification tests, by insisting on regular exercise, and by keeping close contact with all concerned so as to detect early departures from the normal. The medical officer must have absolute authority relative to permitting men to fly so far as physical and mental standards are concerned.

CHAPTER XV

AVIATION ACCIDENTS

Fatal accidents have been associated with aviation since its inception and to a certain extent probably always will be. However, the number of accidents in proportion to the total number of hours flying is constantly decreasing. The number of accidents became proportionately greater during the world war. This was due partly to improper selection of pilots and partly to too rapid training of personnel as well as to other factors which were more or less constant. Even during the world war the number of accidents was not as alarming as many people seem to think; for example, Anderson (1) in a study of accidents at one station during a period of six months found that there had been 58 crashes in 9000 flights and that 16 flyers were injured in these 58 crashes. In other words, there were 28 injuries to every 100 crashes or one injury to every 160 flights. As a result of this investigation, Anderson makes the following statement: "From these figures one can see that school flying is fairly safe and compares favorably with other high velocity forms of transit."

Rowntree (2), in a report of accidents in the United States Air Service, found that 169 flyers had been killed in combat and 245 in accidents in France. He found that for every hundred men who arrived at the front more than 15 were killed in accidents in the training fields of France, while for observers, only 1 out of 100 were killed in training. He found that the incidence of fatalities varied with the type of work; for example, of 2221 taking pursuit training, 49 were killed; of 2486 taking advanced training, 26 were killed, and of 600 taking observation and bombardment training only 6 were killed. He found that from January to October, 1918, inclusive, there were 132,586 hours of flying. There were 550 crashes and 184 fatalities. In the United States, there were 821,259 hours of flying prior to the armistice. There were 263 fatalities, or one fatality for every 3122 hours flown. Accidents were relatively four times as frequent in France as in the United States.

The total deaths of the flying personnel of the United States Air Forces up to 1919 numbered 681. Of these, 508 were due to acci-

dents, 169 to combat and 4 to disease. In the Italian Air Service up to September, 1918, 83 per cent of those killed were killed in accidents. It will, therefore, be seen that aviation accidents form the greatest cause of fatality in the Air Service.

Some of these accidents are inevitable, some are due to mechanical causes, but many are due to physical defect of the pilot. It is the part of the medical service so to select, classify and maintain the flying personnel that the accidents due to physical defect shall be reduced to a minimum. Since 1921 the fatalities in the U. S. Air Service have been reduced from 1 to every 954 hours of flying to 1 to every 3365 hours of flying. This is largely due to the activities of the Flight Surgeons.

Every accident should be investigated carefully as to its cause. Rowntree (2) classifies the causes of accidents as follows: (1) Mechanical imperfections of plane or motor; (2) poor judgment and bad flying; (3) weather conditions; (4) collision; (5) propeller accidents.

The first, mechanical imperfections of motor or plane, concerns the engineering division. This means that the plane and motor must be mechanically fit when selected and must be kept fit by constant care and inspection. An efficient engineering department is absolutely essential for the proper functioning of any flying field. Sufficient personnel must be available to inspect, care for and repair the planes. Rowntree states that it was conceded in France that 6 men on the ground are necessary for every machine that flies. The construction of the ship should have due regard for the safety of the pilot from the standpoint of fire and of his safety in case of an accident. For example, in the old DH4B plane, the pilot's seat was between the motor and the gas tank, a place of practically sure death in case of a crash. The ship should be adaptable to the type of work to be carried on—for example some ships are not suitable for acrobatic work. The pilot should be familiar with the type of plane which he flies and preferably with the individual plane. Each plane flies a little differently and there is a marked difference between types of planes.

Rowntree summarizes the mechanical side by saying, "The essential features are to supply a reliable ship and motor, to keep it fit, to supply proper gas and oil, to see that the ship is used in the type of work for which it is adapted, to see that the pilot is familiar with each new type, its peculiarities and its limitations prior to

flight." The engineering department is responsible for these factors.

Poor judgment and bad flying is the next cause to be considered. Under poor judgment comes physical condition. Physical condition involves all of the factors considered in the previous chapters. It is essential that the flyer be carefully selected, that he be properly classified as to his limitations for altitude, and that the flight surgeon assure the maintenance of his physical fitness through close contact and supervision. It cannot be too strongly emphasized that only those physically fit should be allowed to fly. Minor physical ailments or excesses of any sort result in the development of fatigue or staleness and cause grounding of the flyer. Rowntree states that a good medical principle to follow is: "In general, illness requiring medication is an indication for suspension from flying." He states that three of fifteen fatalities at Issoudun in one month were in flyers convalescent from influenza, none of whom were under observation of the flight surgeon. Fatigue invariably results if over four hours of flying a day are indulged in. Six hours a day is very hard work. When fatigue sets in, judgment is impaired and efficiency is lost. Flying above the pilot's ceiling, determined by his classification test or without use of oxygen at moderately high altitudes are causes of a certain number of accidents. The medical department is responsible for the accidents occurring under this heading.

Bad flying is a result, usually, of inexperience and poor training. In peace time there is little excuse for this, but in war time men are trained rapidly and sometimes inadequately. The pilot must be trained not only in simple flying but in formation flying, acrobatic and combat work. Every well regulated airdrome must have regulations relative to acrobatics, taking off, landings, cross country work, etc. These regulations must be thoroughly understood by the flyers using that airdrome.

Acrobatic work is essential for any flyer not only because of its necessity in combat, but because of the increased confidence it gives the pilot in his machine, in himself, and because of the difficult situations in which he may find himself unexpectedly in even ordinary flying.

Other factors under this heading are recklessness, such as a pilot endeavoring to do acrobatics too close to the ground or in a machine unsuited to acrobatic work. Overcautiousness may cause accidents as well as recklessness. Another factor which is responsible for a



FIG. 33. THE RESULT OF FLYING WITH POOR DEPTH PERCEPTION

This pilot had been directed not to fly for this reason. He thought he knew better but misjudged his distance from a tree

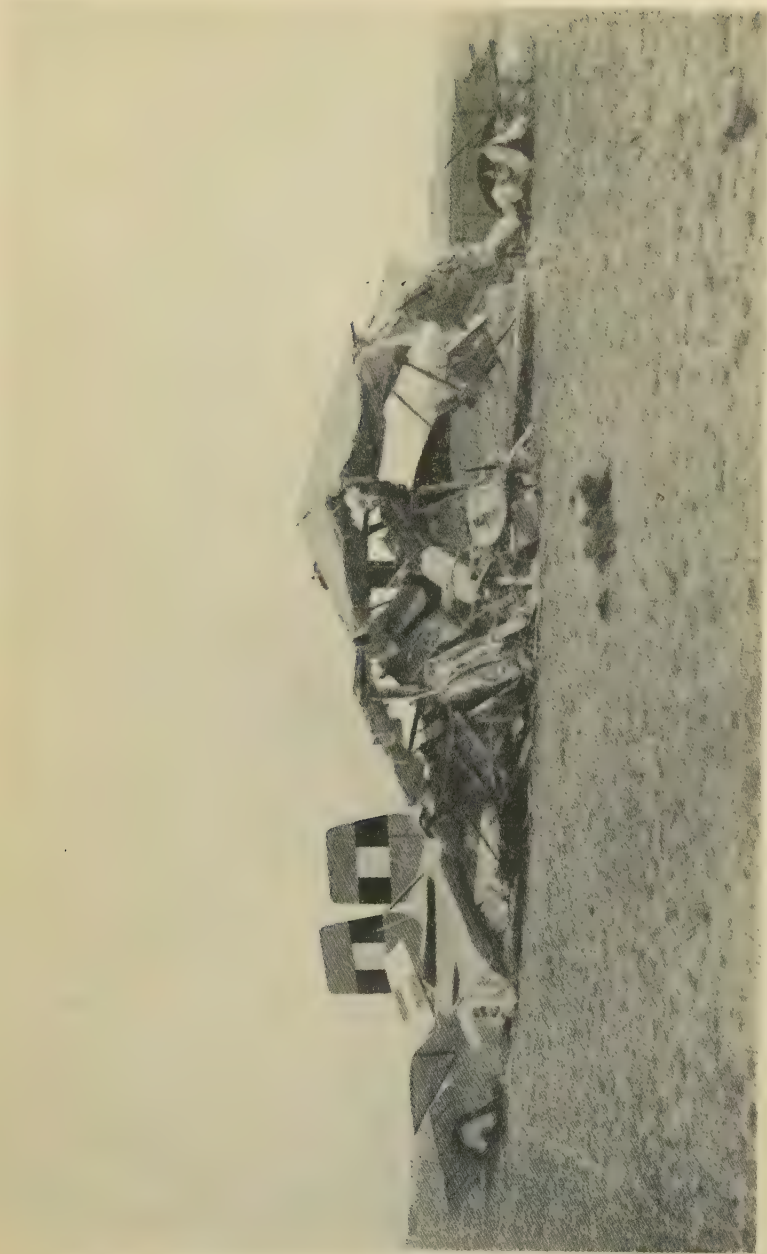


FIG. 34. THE RESULT OF FLYING WHEN PHYSICALLY BELOW PAR

number of deaths particularly during the training period, but also to a certain extent in trained pilots, is turning with a dead motor while taking off. The pilot takes off, the motor quits, his altitude is low, he turns, loses flying speed and either side slips or spins into the ground. Occasionally fright is the cause of an accident. This is particularly apt to happen with a student flyer who loses all judgment and freezes to his controls.

Forced landings are always potential causes of accidents. One never knows when a forced landing may become necessary. The sudden appearance of a storm, the sudden failing of the motor, lack of gas, etc., may result in the necessity for immediate landing. Whether the landing is negotiated successfully or not depends upon weather conditions, upon the terrain and upon the coolheadedness of the pilot.

Air conditions. Under this heading come winds, clouds, and holes, all of which are considered menacing to flying. Winds are particularly dangerous during the take-off, especially if gusty. Clouds are dangerous when close to the ground. With modern airplanes holes in the atmosphere are less dangerous but are a danger nevertheless.

Collisions, when not due to carelessness or poor vision of the pilot are due to the blind angles of the machine. They happen in formation flying or when flying in fogs or clouds. Proper regulations relative to taking off and landing at the airdrome will prevent a certain number of collisions.

When an airplane has to be cranked, there is always a certain danger of injury by the propeller. The propeller causes a strong suction when it starts and a person is apt to be drawn into it. These injuries are very severe as a rule.

Rowntree (2) states that the responsibility of the medical department is as follows.

The Medical Service is responsible for physical fitness. It should see:

- (1) That only those fit to fly be admitted to the service.
- (2) That, through investigations (clinical and laboratory), standards be determined covering every function which relates to flying.
- (3) That maximum efficiency be maintained, through supervision and regulation of the life of the flyer, in regard to such matters as exercise, sleep, diet, habits, etc.
- (4) That an effective mechanism to meet these needs be supplied through flight surgeons, laboratories, etc. and through the establishment of the proper relations between the flying personnel and the Medical Department.
- (5) That flyers not making satisfactory progress in training be investigated medically.

(6) That flyers not making proper progress in training, who exhibit physical or mental unfitness from any point of view, be properly cared for. This includes proper medication, sound advice, periods of rest, hospitalization, etc., and involves the provision of properly manned institutions for this purpose.

(7) That the medical and training departments coöperate in an effort to overcome disability of any kind.

(8) That all permanently unfit be removed from flying status. These may represent mistakes in admission or may result from conditions arising subsequent to admission.

(9) That all medical information concerning the flyer be available for the medical officer into whose hands the flyer comes in the event of emergency or illness. This involves an adequate system of records.

(10) That the Medical Service be granted authority sufficient to render action possible for the prevention of accidents. The Medical Department should have authority to say that a man may or may not fly and in the latter event to dispose of him as it sees fit.

(11) That no flyer be returned to flying status unless physically fit.

(12) That the Medical Service be allowed to participate in the investigation of accidents from the medical point of view to determine the responsibility involved.

(13) That men be grouped, so far as possible, relative to their aptitude or fitness for various types of work. This involves classification from the standpoint of withstanding altitude effects and from the standpoint of physical and temperamental fitness of the individual flyer for various types of work.

(14) That all information concerning the progress and maintenance of efficiency of the flyer be supplied to the flyer and to the administration. This involves such questions as supply of oxygen, goggles, protection from cold, wind, etc.

Anderson (1) classifies aviation accidents slightly differently. He places them under the following heads: defects in airplane, error in judgment, loss of head, brain fatigue or lethargy, fear, physical illness, and unavoidable. Those due to error in judgment may be caused by underinstruction, subnormal vision, delayed reaction time, either habitual or temporarily caused by fatigue, drugs, excesses. Fear, he says, is an uncommon cause, as the aviator is too busy to be afraid.

In attending an aviation accident the ambulance should carry the following equipment: a crowbar, wire cutters, saw, axe, cloth-cutting scissors and a fire extinguisher. The machine should be cut away from the aviator, for he is usually severely injured and suffering from shock. The ambulance should also carry a first aid kit consisting of chloroform and mask, brandy or whisky, morphine, hypodermic, sterile water, tourniquet, knife, first aid dressings, slings, splints and some sort of dressing for burns.

Anderson (1) classifies injuries as follows: those from crushing, collision, impact, fire, drowning, immersion and suspension affects. Injuries are apt to be multiple and severe. There is a likelihood of a shattering of the long bones and of cuts and injuries about the face and head. Fractures of the skull are common. If the vault is fractured there is usually so much crushing that death ensues. Frequently, however, there is a fracture of the base alone. Fractures of upper and lower jaws and nose are very common due to the flyer's head striking against the cowl, instrument board or gun rack. Fractures of the legs are more common than those of the arms, particularly fractures of the lower legs. In falls from a great height or at a great speed, the engine is driven back on the man in the front seat and all the bones are shattered. Anderson (1) calls attention to the frequent fracture of the astragalus.

Burns of severe character result when the plane catches on fire. If the plane strikes the ground while the motor is still going fire is almost inevitable. Usually the flyer is pinned under the wreck so that even if conscious he is unable to extricate himself and he is bound to be severely burned.

Frostbite is common on flights to high altitudes where extreme cold is encountered.

The man in the front seat is more apt to be injured than the man in the rear seat, because of the danger of the telescoping of the engine into the front seat, or the danger of long splinters from the landing gear being driven up through the floor of the front cockpit and impaling the pilot.

It must be remembered a plane crashes oftentimes with terrific velocity and severe injuries and shock are bound to occur.

The injured man must be handled with great care to avoid further injury.

The treatment of aviation accidents does not require any special knowledge other than that necessary for the treatment of any injury of the surgical type.

THE AIRPLANE AMBULANCE

The use of airplane ambulances was first developed during the world war and the ambulance consisted of a remodeled observation plane capable of transporting one or, at the most, two passengers. We now have planes capable of transporting several patients reclining and sitting together with an attendant. It should be equipped with

modified Stokes litters which are really wire baskets that hold the patient very comfortably. The ambulance was first developed with the idea of attending crashes. It has, however, a rather limited field in this regard. Usually a crash occurs because a plane could not make a proper landing and this will militate against the use of an airplane ambulance. Its great field will be in the transporting of patients from the front to the rear in the theatre of operations particularly those which heretofore have been considered nontransportable because of shock. There is no comparison between transportation by an airplane and by a motor ambulance. There is absolutely no jarring and no shock from transportation by airplane ambulance and its use will save many lives. It is particularly useful in cases where transportation must be slow and of a primitive nature, such as in Morocco and Mesopotamia where the French in the former and the British in the latter have used the airplane ambulance extensively in transporting their patients from the scene of operations to the base. Transportation in Morocco, for example has become a matter of hours where before it was days.

It is believed therefore that the airplane ambulance will become more and more recognized as a valuable means of transporting the sick and wounded in war time for not only can it transport the patient with practically no shock but it is a great time saver, sometimes over great distances to adequate surgical attention.

The Douglas transport type will accommodate four litter patients and two sitting, besides a medical officer and a pilot. The Cox-Kremlin model will take two litter patients, a medical officer and a pilot. It is also equipped with a cabinet for first aid dressings.

REFERENCES

- (1) ANDERSON, H. G.: The medical and surgical aspects of aviation. 1919. Oxford Medical Publications.
- (2) ROWNTREE, L. G.: Aviation accidents. In *Aviation Medicine in the A. E. F.* Washington, 1920, Chapter VII.

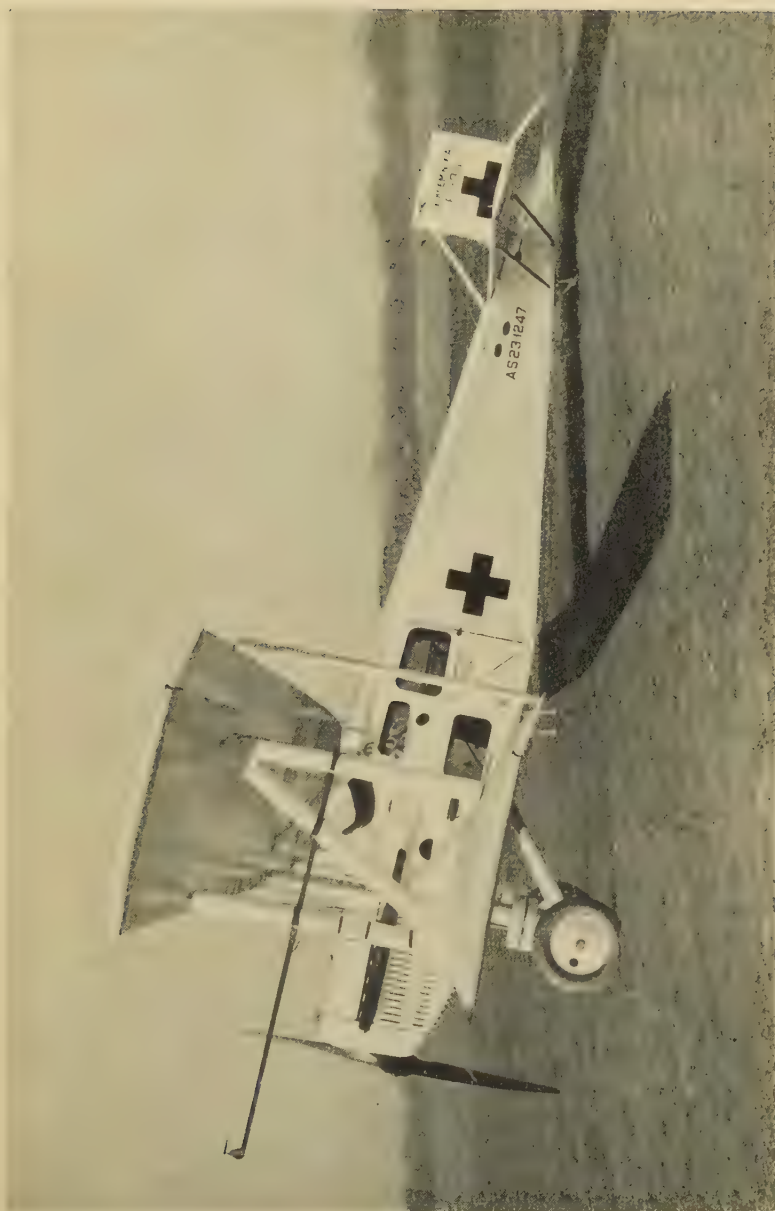


FIG. 35. AIRPLANE AMBULANCE (COX-KREMLIN)
Carries pilot, medical officer, and two litter patients

CHAPTER XVI

AIRPLANE DOPE POISONING

While airplane dope poisoning has nothing to do with flying, nevertheless the medical officer on duty with the Air Service will be called upon to make recommendations relative to dope workers and the construction of dope rooms, and occasionally to treat the victims of poisoning. Hence it seems worth while to consider the matter briefly in this book.

Airplane dope is a substance used on the surface of the fabrics covering the wings and bodies of airplanes. Its composition is varied from time to time and at present is a much less dangerous substance than was used early in the war. The composition of one dope commonly used, is as follows:

	<i>per cent</i>
Butyl acetate.....	22
Ethyl acetate.....	44
Denatured alcohol.....	2
Benzol.....	32

Other substances often used are: acetic anhydride, benzol, benzyl acetate, benzyl benzoate, diacetone alcohol, methyl ethyl ketone, triphenyl phosphate, urea, cellulose acetate, acetone, amyl acetate, and tetrachlorethane.

Amyl acetate is now used very little. Tetrachlorethane was formerly used in all dope and is an exceedingly dangerous chemical. It was found that workers with dope in which tetrachlorethane was used frequently suffered from toxic jaundice. There was loss of weight, drowsiness, disturbances of metabolism and in chronic poisoning, solution of red corpuscles, basophilia, fatty liver, fatty heart muscle, yellowish and congested kidneys. There was jaundice and sometimes atrophy of the liver. Because of the extreme danger of this substance it has gradually been eliminated until now it is practically never used. In this country specifications for dope usually prescribe that the formula shall be free from substances which would be injurious to workmen. This however, is not quite the case in practice.

Some of the substances contained in dope and their actions are as follows:

Methyl and ethyl acetate are somewhat narcotic. Acetone is a feeble narcotic, causing dyspnoea. Fifteen to 20 cc. given to a man causes headache, but otherwise there is no effect. Methyl ethyl ketone has an action similar to that of acetone. Inhalation of coal tar benzene causes headache, giddiness, malaise, twitchings, convulsions and unconsciousness. If large quantities are inhaled death may occur suddenly or after a short illness with symptoms of vertigo. Chronic poisoning causes anemia, vomiting, fever, and fatty degeneration of the endothelium of blood vessels and other organs. Benzyl acetate and benzoate cause relaxation of all smooth muscles.

Benzene usually is not present to a greater extent than 12 to 15 per cent in dope. From that amount one would look not for acute severe poisoning but rather for slight forms such as dizziness, headache and transient excitement followed by depression and nausea. It would seem that workers in fumes of amyl acetate may suffer from smarting eyes, dry throat, obstinate cough, dizziness, drowsiness, weariness and possibly long continued exposure may produce changes in the organs, especially the liver. Methyl alcohol, by inhalation, may be dangerous although it usually is present in such small amount as to render the danger slight.

Men complain of headache and nausea when working for any length of time in dope rooms. Usually there is loss of appetite and constipation. The men may collapse and have to be removed to fresh air. With the substances now used in dope there is little excuse for men showing serious effects of dope poisoning. The dope room should be so constructed that there is a down draft in the room. The air inlet should be at the top at one end of the room and there should be an exhaust fan or fans at the other end of the room near the floor. Dope fumes tend to fall, consequently workers should stand on a platform built of slats so that the dope fumes fall through the slats into the trough at the end of which are the exhaust fans. Dope rooms have to be kept at a high temperature—70° to 80°F., usually—so that the dope will take well. It may therefore be necessary to warm the air during the winter months. This can be done by passing the inlet air pipe through a warm room before it enters the dope room or by placing steam pipes in close proximity to an air inlet.

Dope workers should be inspected at least once a month and a

careful examination should be made, with particular reference to the blood, urine, and the presence or absence of toxic symptoms. Dope workers should be required to go out into the open air about five minutes in every hour, and they should not be allowed to stay in the workroom except when actually working. It is exceedingly important that the bowels should be kept free. The use of milk has been urged, although it is probably less important now than it was when tetrachlorethane was used. Milk is recommended for the following reasons: Milk is a protein diet favorable because of its easy digestibility and its large amount of fluid which favors better kidney action. Whole milk contains 3.5 per cent or more of butter fat beside some compound fats. The action of the soluble dope poisons that reach the bowel, will therefore, be favorably modified and to some extent probably eliminated unabsorbed, held in solution in the calcium soaps formed from the milk fats during digestion. It is recommended that one or two quarts daily be given to dope workers to be taken during their working hours. If possible, dope workers should not be kept at the work over any considerable period of time but preferably should be switched to some other work every two months, another crew taking their place.

CHAPTER XVII

CIVILIAN AVIATION

Commercial aviation in America is still largely undeveloped. Only spasmodic efforts have been carried out. Plans are underway, however, for development of both passenger and freight lines. Commercial lines are fairly numerous and quite successful in Europe. Eventually air lines are bound to cover the civilized world.

Most countries have recognized the necessity for proper examination and licensing of pilots and operating crews. The International Congress for Air Navigation has drawn up minimum requirements for those engaged in international air transport. This convention has not yet been ratified by the United States, and there is no federal law governing aviation. As a result only the pilots of the Army, Navy, Marine Corps, and Post Office Department are required to take any examination either medical or technical. This situation is a ridiculous one. A pilot rejected as unfit either physically or technically by the government services can hire a civilian plane and fly, endangering not only himself but others and property.

While the physical requirements for commercial flying need not necessarily be as strict as those for military flying, nevertheless a high standard is essential. Commercial pilots rarely ascend to great altitudes so that altitude classification is not necessary. Neither do commercial pilots engage in the various types of flying that military pilots do. However, they fly regularly, put in a large number of hours in the air, have great responsibility, particularly when carrying passengers and are subject to fatigue and staleness. They need good eyes and nervous stability. Their requirements should conform at least to those of the International Commission for Air Navigation.

These requirements are of two standards, one for flyers engaged in public transport, and one for private pilots. The second class has a less rigid examination.

Both classes, however, are required to undergo reexamination every six months.

It is essential that care be used in the selection of flyers no matter

what their duties and that they be kept under supervision. As pointed out in a previous chapter, the civilian flight surgeon has not yet come into being, but his services are going to be needed and before long will be considered absolutely essential.

The medical requirements of the International Commission already referred to follow:

MEDICAL CERTIFICATES

INTERNATIONAL MEDICAL REQUIREMENTS FOR AIR NAVIGATION

PUBLIC TRANSPORT

1. Every candidate before obtaining a license as a pilot, navigator, engineer, or member of the operating crew of aircraft engaged in public transport will present himself for examination by specially qualified medical men (flight surgeons), appointed by or acting under the authority of the contracting State.

2. The candidate, before undergoing the examination referred to in paragraph 1 above, must have successfully undergone a preliminary medical examination at which he must have satisfied the following minimal requirements as to physical fitness.

He must be of the male sex, must have the complete use of his four limbs, must not be completely deprived of the use of either eye, must be free from active or latent, acute or chronic, medical or surgical disability or infection. He must be free from any injury or wound which would entail any degree of functional incapacity which might interfere with the safe handling of aircraft at all altitudes and even in cases of prolonged or difficult flight. He must be completely free from hernia, must not suffer from any detectable sensory lesion, and must be free from a history of morbid mental or nervous trouble.

3. Medical supervision, both for the selection and the maintenance of efficiency of the personnel specified in paragraph 1, shall be based upon the following requirements of mental and physical fitness:

(a) Good family and personal history, with particular reference to nervous stability, as to which information shall be given at the first examination in a statement made and signed by the candidate and satisfactory to the examining officer. Absence of any mental, moral, or physical defect which will interfere with the safety of air navigation.

(b) Pilots and navigators of aircraft engaged in public transport may not enter upon their duties before nineteen or after forty-five years of age.

(c) General Surgical Examination. The candidate must neither suffer from any wound or injury, nor have undergone any operation, nor possess any abnormality, congenital or acquired, which might interfere with the safe handling of aircraft at any altitude even in the case of prolonged or difficult flight.

(d) General Medical Examination. The candidate must not suffer from any disease or disability which renders him liable suddenly to become incompetent in the management of aircraft. He must not have any signs of

aneurism of the large arterial trunks, nor have any cardiac lesion, even if well compensated; the heart must be normal, with normal function, and only respiratory arrhythmia, increase of pulse rate from excitement or exercise and a general slow pulse not associated with auriculo-ventricular dissociation will be allowed. He must possess lungs and nervous system in a state to withstand the effects of altitudes and also the effects of prolonged flight. He must be free from kidney disease, and must not present any clinical signs of syphilis.

(e) Eye Examination. The candidate must possess a degree of visual acuity compatible with the efficient performance of his duties. Pilots and navigators must possess visual acuity equal to 100 per cent for each eye taken separately and without correction by glasses, the visual acuity being measured by means of a powerful illumination not shining directly into the eyes of the examinee. Binocular vision, ocular poise, the field of vision of each eye and color perception must be normal.

(f) Ear Examination. The middle ear must be healthy. The candidate must possess an auditory acuity not less than that corresponding with the normal perception of the tuning forks C (1) 64 vibrations per second, C (3) 256 vibrations per second, and C (7) 4096 vibrations per second, the forks being held perpendicularly to the ground one centimeter from the auditory tube. The vestibular mechanism must be intact and not hypersensitive; it must be equal on both sides.

(g) Nose, Throat and Mouth Examination. The candidate must possess free nasal and tubal air entry on both sides and must not suffer from serious, acute or chronic affections of the buccal cavity or upper respiratory tract.

4. Each Contracting State shall provisionally fix its own methods of examination, until the details and the minimal conditions of the tests shall have been settled by a decision of the International Commission for Air Navigation adopted by the minority provided for in article 34 for modifications of the provisions of the Annexes. Such details and minimal conditions may be modified by the International Commission for Air Navigation by the same majority.

5. The successful candidate will receive a medical certificate of acceptance, which must be produced before the license can be issued or renewed.

6. In order to ensure the maintenance of efficiency, every member of the personnel specified in paragraph 1, who holds a license, shall be reexamined periodically, at least every six months, and the findings shall be attached to his original record. In case of illness or accident also, he shall be reexamined and pronounced fit before resuming air duties. The date and result of such reexamination shall be recorded on the license of the person examined.

7. Any member of the operating crew of an aircraft, certificated before the 1st of January, 1919, and serving on the 1st of July, 1922 in a public transport company, may be retained in the navigating personnel so long as his physical capacities as ascertained at his last medical examination are maintained unless there be detected a pathological defect capable of causing a sudden accident.

8. Each Contracting State may raise the conditions set forth above, as it deems fit, but these minimal requirements shall be maintained internationally.

STANDARD FORM OF MEDICAL CERTIFICATE

Valid until.....

MEDICAL CERTIFICATE

I, the undersigned
 certify that (1).....
 born at the
 domiciled at has undergone an
 examination as to physical fitness and that he has been found
 (2).....
 to serve in the operating crew as (3).....

Given at the day of 19...

.....
 Signature

- (1) Name and Christian names.
- (2) Fit, unfit, or temporarily unfit.
- (3) Indication of capacity in which to be employed in the operating crew.

The Commission decides that every candidate for a private pilot's license shall present a medical certificate, granted after a preliminary medical examination, which it shall not be compulsory to undergo thereafter for the renewal of such license.

INTERNATIONAL MEDICAL REQUIREMENTS FOR AIR NAVIGATION

PRIVATE PILOTS (FLYING MACHINES)

1. Every candidate before obtaining a private pilots' license will present himself for an examination by qualified medical men specially appointed by or acting under the authority of the contracting States.

2. This medical examination shall be based upon the following requirements of mental and physical fitness.

(a) Good family and personal history, with particular reference to nervous stability, as to which information shall be given in a statement made and signed by the candidate and satisfactory to the examiner.

(b) Candidates for private licenses (flying machines) may not apply for a license before the age of 17.

(c) General Surgical Examination. The candidate must suffer neither from any wound or injury nor have undergone any operation, nor possess any abnormality, congenital or acquired, which might interfere with the safe handling of aircraft under ordinary conditions.

(d) General Medical Examination. The candidate must not suffer from any disease or disability which renders him liable suddenly to become incompetent in the management of aircraft. He must possess heart, lungs and kidneys in a state to withstand the effects of altitude. He must be free from kidney disease, and must not present any clinical signs of syphilis, nor have any cardiac lesion.

(e) Eye Examination. The candidate must possess a degree of visual acuity equal to 6/9 for both eyes with correction by glasses if necessary, the visual acuity being measured by means of a powerful illumination not shining directly into the eyes of the examinee. Ocular poise, the field of vision of each eye and color perception must be normal.

(f) Ear Examination. The middle ear must be healthy. The candidate must possess an auditory acuity not less than that corresponding to the whispered voice at one meter. The vestibular mechanism must be intact and not hypersensitive. It must be equal on both sides.

(g) Nose, Throat and Mouth Examination. The candidate must possess free tubal air entry on both sides.

3. Each contracting state shall provisionally fix its own methods of examination until the details and minimal conditions of the tests shall have been settled by a decision of the International Commission for Air Navigation adopted by the majority provided for in article 34 for modifications of the provision of the Annexes. Such details and minimal conditions may be modified by the International Commission for Air Navigation by the same majority.

4. The successful candidate will receive a medical certificate of acceptance which must be produced before the license can be issued. This medical certificate must, as far as possible, be in accordance with the following form.

MEDICAL CERTIFICATE

Valid until.....
 I, the undersigned.....
 certify that (1).....
 born at.....the.....
 domiciled at.....has undergone an
 examination as to physical fitness and that he has been found
 (2).....
 to serve as a private pilot (flying machines).

Given at.....the....day of.....

.....
 Signature

(1) Name, Christian names and sex.

(2) Fit, unfit, or temporarily unfit.

5. Any aircraft pilot certified before the 28th of June, 1925, will be considered as having fulfilled the requirements mentioned above for the granting of a certificate of physical fitness unless he should be found to have a pathological defect capable of causing a sudden accident.

6. Each contracting State may raise the conditions set forth above, as it deems fit, but these minimal requirements shall be maintained internationally.

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SUPPLEMENT

DIRECTIONS FOR PROCEDURE IN THE CIRCULATORY EFFICIENCY TEST (SCHNEIDER INDEX)

Preliminary: Subject reclines for five minutes.

1. Heart rate is counted for 20 seconds. When two consecutive 20 second counts are the same this is multiplied by 3 and recorded.

TABLE 1
Points for grading cardiovascular changes. (Schneider Index)

A. RECLINING PULSE RATE		B. PULSE RATE INCREASE ON STANDING				
Rate	Points	0-10 beats, points	11-18 beats, points	19-26 beats, points	27-34 beats, points	35-42 beats, points
50-60	3	3	3	2	1	0
61-70	3	3	2	1	0	-1
71-80	2	3	2	0	-1	-2
81-90	1	2	1	-1	-2	-3
91-100	0	1	0	-2	-3	-3
101-110	-1	0	-1	-3	-3	-3

C. STANDING PULSE RATE		D. PULSE RATE INCREASE IMMEDIATELY AFTER EXERCISE				
Rate	Points	0-10 beats, points	11-20 beats, points	21-30 beats, points	31-40 beats, points	41-50 beats, points
60- 70	3	3	3	2	1	0
71- 80	3	3	2	1	0	0
81- 90	2	3	2	1	0	-1
91-100	1	2	1	0	-1	-2
101-110	1	1	0	-1	-2	-3
111-120	0	1	-1	-2	-3	-3
121-130	0	0	-2	-3	-3	-3
131-140	-1	0	-3	-3	-3	-3

E. RETURN OF PULSE RATE TO STANDING NORMAL AFTER EXERCISE		F. SYSTOLIC PRESSURE, STANDING, COMPARED WITH RECLINING	
Seconds	Points	Change in millimeters	Points
0- 30.....	3	Rise of 8 or more.....	3
31- 60.....	2	Rise of 2-7.....	2
61- 90.....	1	No rise.....	1
91-120.....	0	Fall of 2-5.....	0
After 120: 2-10 beats above normal.....	-1	Fall of 6 or more.....	-1
After 120: 11-30 beats above normal.....	-2		

2. The systolic pressure is taken by auscultation and recorded. Take two or three readings to be certain.

3. The subject then rises and stands for two minutes to allow the pulse to assume a uniform rate. When two consecutive 15 second counts are the same, multiply by 4 and record. This is the normal standing rate.

4. Standing pulse minus the reclining pulse gives the increase on standing.

5. The systolic pressure is taken as before and recorded.

6. Timed by a stopwatch, the subject steps upon a chair $18\frac{1}{2}$ inches high five times in 15 seconds. To make this uniform the subject stands with one foot on the chair at the count one. This foot remains on the chair and is not brought to the floor again until after count five. At each count he brings the other foot on the chair and at the count "down" replaces it on the floor. This should be timed accurately so that at the 15 second mark on the stopwatch both feet are on the floor.

7. Start counting the pulse immediately at the 15 second mark on the stopwatch and count for 15 seconds. Multiply by 4 and record.

8. Continue to take pulse in 15 second counts until the rate has returned to the normal standing rate. Note the number of seconds it takes for this return and record. In computing this return count from the end of the 15 seconds of exercise to the beginning of the first normal 15 second pulse count. If the pulse has not returned to normal at the end of 2 minutes record the number of beats above normal and discontinue counting.

9. Check up points and enter final rating.

10. Enter history of case, including amount of sleep, amount of smoking, kind of work, (outdoor or indoor, active or sedentary, etc.) time since last meal, any personal worries or any pathological condition which might affect the condition of the subject.

GENERAL INSTRUCTIONS FOR THE CONDUCT OF ALTITUDE CLASSIFICATION TESTS (REBREATHING EXAMINATION)

1. Each unit will consist of two enlisted men, one of whom will be qualified to take blood pressures and pulse rate, and the other qualified to operate the machine and keep the respiratory record. Both of them will be qualified to do plotting and gas analysis. One Flight Surgeon will be in charge of the unit and will act as clinician, another will act as psychologist.

2. The routine test for the aviators will consist of (a) preliminary test by clinician and physiologist including history, (b) test on the Henderson Rebreathing Apparatus during which the subject's performance and condition are observed by clinician and psychologist. Technical details of the test are the responsibility of the physiologist who supervises the work of the enlisted men on the machine and in taking pulse and blood-pressure. He will not examine the subject during the test.

3. The test will normally be continued until the subject has arrived at a point where he clearly shows low oxygen effects of his efficiency as determined by the Psychologist, and when this point is reached the experiment will be terminated. In case, however, his general condition demands it, the subject should be removed before this time. The necessity for interrupting

the test before its natural termination is to be decided by the clinician, though all present should be prepared to call his attention to unfavorable indications. This applies especially to the Physiologist and the enlisted man taking pulse and blood-pressure, who should promptly report to the clinician any noteworthy change in these observations or in the respiration.

4. No test should be prolonged beyond the point where the final rating can be determined. For example; if the subject's heart puts him in class "C" or "D," it is a matter of no great interest whether he ranks "A" or "B" on the psychological test. *It is important that the test be so conducted that subjects will not have the expectation in advance of undergoing anything dangerous or disagreeable;* for this reason tests should rarely be prolonged to the point of fainting, unconsciousness or other great discomfort.

5. All members of the unit must exercise diligent care to prevent the prejudicing, alarming or exciting of the subject. This applies not only to subjects being tested, but to all fliers and candidates who may later be subjects for the test. Even chance remarks, which might give the impression that there is danger or discomfort in the test, or that many men are disqualified as a result of the test, must be scrupulously avoided. Unfortunate remarks which seem unimportant to the person making them, do in many cases produce such an effect on the subject that his performance on the test is materially modified.

6. Instructions to the aviator, concerning the operation of the psychological apparatus, will be given *by the psychologist only*. Additions by other members of the group are detrimental. These instructions will not be given until after the preliminary pulse and blood pressure readings are taken.

7. During the first three minutes of the run, the aviator will be coached by the psychologist.

8. Stopwatches of the psychologist, physiologist and clinician will be started simultaneously, and all records will be kept in terms of elapsed time after watches are started.

9. Results should not be indicated to the aviator except in the most general form—especially to be avoided is any statement of "how far he went" in terms of thousands of feet altitude. It may be made plain that there is no direct parallel between oxygen percentage in the rebreathing test and low atmospheric pressure, and that in the rapid progression of the test the results would be very fallacious if applied to active working conditions at high altitudes.

10. The physiologist may suggest terminating the test if something is manifestly wrong as, e.g., with the apparatus.

11. The clinician will, himself, inquire in regard to the details of present health and fitness at the time of the rebreathing test. Any condition of present health or fitness other than "good" should be fully explained. An accurate knowledge of these factors is extremely important because of their influence upon the character of the run, and the frequent necessity of considering the advisability of a second run. In this connection it is to be remembered that a low rating, which results from a temporarily acting cause, is as unfair to the government as it is unjust to the flier.

12. The heart examination will be carefully recorded. Some clinicians have endeavored so to record their findings, that the School of Aviation Medicine may make the diagnosis of the heart condition. This is clearly impossible. In every case of abnormal findings the clinician himself will definitely make a diagnosis, especially in case of murmurs or other signs of doubtful significance. In the absence of a positive diagnosis of organic disease, the Laboratory assumes that the clinician believes the heart to be normal. The quality of heart sounds and murmurs should be described as accurately as possible. Relative accentuation and length, (whether prolonged or short and sharp), are useful terms of description of heart sounds and should be recorded. The time, the point of maximum intensity, and the transmission of murmurs should also be recorded. When the clinician, after considering all the data, is unable to make a positive diagnosis of the presence or absence of organic heart disease, it is permissible to repeat the rebreathing test.

13. Under the heading "General Impression, psychological," note whether there is evidence of active or passive resistance, indifference, or coöperation in carrying on the rebreather test. Record evidences of apathy, nervousness, undue apprehension as well as exaggerated interest in results, or any signs of resentment or definite opposition to the technique of the examination.

14. Under "Summary of Observations During Low Tension Test," attention is invited to the following: After "Exact condition at close of test" should be noted conscious, unconscious, cyanotic, pale, etc. After "recovery" Prompt or Slow, etc.

The names of the observers will be noted carefully in the proper places.

Each observer will fill in the rating with appropriate remarks in the proper place. The letter "A," "B," or "C," etc. designating each rating will be placed before the word "clinical," "physiological," and "psychological."

15. Under "Recommendations of Board as to Fitness of Aviator" will be given the final rating (to the left).

16. The final rating will always be the lowest of the three ratings,—clinical, physiological or psychological. Class "A" is unrestricted; Class "B" is restricted to not more than 15,000 feet; and Class "C" is restricted to not more than 8000 feet.

17. The ratings "Class A," "Class B," etc., will be immediately followed by an explanation of the meaning of the classification in terms indicating the maximum altitude to which the officer may fly, viz:

Class A (No restrictions as to altitude)

Class B (Should not fly above 15000 feet)

Class C (Should not fly above 8000 feet)

Class D (Should not fly at all)

18. The meaning of the classification will be followed immediately by a brief statement of the reason for the classification and recommendation, if the rating is other than "A." As these recommendations and explanations are mainly for the information of the commanding officer, who is a layman, they should invariably be in non-technical language. Such terms as "motor attention," "inefficiency," "circulatory break," etc., will be avoided.

19. It is desirable that these recommendations should be uniform in so far as they refer to the same types of runs. The following forms will, therefore, be adhered to whenever they are applicable

1. Class A. (No restrictions.)
2. Class B. (Should not fly above 15,000 feet.) Becomes inefficient before highest altitudes are reached.
3. Class B. (Should not fly above 15,000 feet.) Circulatory system shows poor compensation, and he has a tendency to faint before the highest altitudes are reached.
4. Class B. (Should not fly above 15,000 feet.) Has a high blood pressure. Would not wear well if used at highest altitudes. Should be watched for wear.
5. Class B. (Should not fly above 15,000 feet.) Preserves efficiency at expense of severe circulatory strain. Should be watched for wear.
6. Class C. (Should not fly above 8,000 feet.) Becomes inefficient at moderate altitudes.
7. Class C. (Should not fly above 8,000 feet.) Circulatory system shows strain at moderate altitudes.
8. Class C. (Should not fly above 8,000 feet.) High blood pressure. Would wear out quickly if used at higher altitudes. Should be watched for wear.
9. Class C. (Should not fly above 8,000 feet.) Nervous type. High pulse and blood pressure. Would wear out quickly if used for high work. Should be watched.
10. Class D. (Should not fly at all.) Has organic heart disease. Should be sent to hospital for observation or recommended for a retiring board.

20. Care will be taken that the reason given for the rating is correct. Not infrequently the explanation "Becomes inefficient etc." is given when the test was terminated because of impending circulatory collapse. The term "inefficiency" will be used only for psychic and mental failure such as "motor incoördination," "attention breaks," etc. Circulatory incompetence will be explained as "impending circulatory collapse," or "fainting," rarely as "circulatory fatigue," never as "inefficiency."

21. The above phrases, properly combined or slightly modified, will apply in over 90 per cent of the cases. Exceptionally it may be desirable or even necessary to give other reasons for the rating.

22. It is probable that runs vary in length and amount of O_2 consumed according to the temperature prevailing at the time of the test. Accordingly the room temperature in degrees Fahrenheit will be recorded under "Remarks" in the "Summary of Observations."

INSTRUCTIONS TO MACHINE MEN

(These instructions will be observed strictly and in the order mentioned)

HENDERSON REBREATHING

A perfect experiment requires that the rebreathing machine be in perfect order. Leaks of water and air into and from the machine must be avoided.

Water may be flowing into the tank during an experiment through the inlet valve either because it is not perfectly closed or is out of repair. Water may be escaping through the outlet valve for the same reasons. Leaks of air may be due to the faulty and improperly closed valves or too loose fitting mouth parts. Occasionally a candidate may be found who sucks the air and allows it to escape by not keeping his lips closed tightly around the rubber mouth-piece.

The movement of air through the rebreathing machine must be free so that the breathing of the candidate is not hampered. It is necessary to test frequently the resistance offered by the absorption cartridge.

TO PREPARE THE REBREATHING MACHINE FOR AN EXPERIMENT

I. Absorbent cartridge

1. Before each experiment the resistance of the absorbent cartridge should be ascertained by gently blowing through the expiration tube and the cartridge. The gate valve below the absorbent cartridge must be open and all other valves closed during the test. The spirometer can be raised easily if the NaOH is uncaked and open.

2. Read the time slip on the cartridge and be sure the cartridge has not been used more than 145 minutes. The cartridge must be removed after 175 minutes of rebreathing and at least 30 minutes should be allowed for a run, therefore, the run must not be started with a cartridge which has been used for more than 145 minutes. To insert a new cartridge when necessary proceed as follows:

- a. Punch both cardboard ends of the cartridge full of holes about $\frac{3}{8}$ inch in diameter.
- b. Insert the loose brass ring inside the lower rim of the pasteboard cartridge.
- c. Put the rubber gasket around the outside of the lower rim.
- d. Insert cartridge, with the marked end up, into the steel case.
- e. Tighten the thumb screw over the rubber gasket.

II. The machine

1. Close the gate valve just beneath the absorbent cartridge.
2. Close the gate valve protecting the return pipe from the tank to the subject.
3. Open gate valve on spirometer pipe.
4. Open water inlet valve. Carefully fill the tank with water forcing out all of the air in the tank. (Do not let the tank overflow.)
5. While the tank is full, raise and lower the spirometer can half a dozen times to insure a thorough flushing of all its dead space.
6. Open the valve in the expiration pipe, close the valve in the spirometer pipe, open drain valve and drain water out about half way down. This purifies the expiration pipe.
7. Close valve in expiration pipe, open valve in spirometer pipe, open water inlet valve and again fill tank with water. Close water inlet valve.
8. Flush spirometer can six times again.

9. Open drain valve and drain water out about half way down. Close drain valve. Close spirometer pipe valve and open inspiration pipe valve. Open water inlet valve and fill tank with water. This purifies the inspiratory pipe. Close water inlet valve.

10. Close inspiratory pipe valve, open spirometer pipe valve, open drain, valve and allow water to run out until it reaches the proper level as indicated on the water gauge.

11. Raise spirometer to proper level for 52 liters of air. Close spirometer pipe valve.

12. When a run is to be started, open the valves to the inspiratory and expiratory pipes on signal from the physiologist.

13. In flushing the type of machine in which the inspiratory and expiratory pipe valves are controlled by one lever, flush exactly as above except that when the directions call for opening or closing or either the inspiratory or expiratory pipe valves, operate this lever instead, regardless of the fact that this lever operates both valves at the same time.

III. Accessories

1. The mouth-piece, rubber tubes and nose-clips should be ready for use.
2. A roll of paper towel or a large piece of gauze should be placed on the rebreather behind the subject, but in a convenient place for the physiologist.

IV. The kymograph

1. Lay the kymograph paper on the table, with a glazed side down and the glued end away from you.

2. Remove drum from kymograph.

3. Hold the drum with the top to the right and lay it across the middle of the paper.

4. Bring both ends of the paper toward each other, letting the glued end overlap.

5. Moisten the glued end and fasten it firmly to the glazed side of the unglued end so that the paper is wrapped tightly around the drum.

6. Smoke the drum over the flame of an oil burner or a fishtail gas burner while revolving the drum rapidly. Smoke drum until it is coated to a light brown color.

7. Replace the smoked drum on the kymograph.

8. Place the kymograph on the shelf of the rebreathing machine in such a position that the stylus of the spirometer will record its movements evenly and completely on the smoked drum. Set the stylus about 3 centimeters from the lower edge of the drum.

9. Connect the signal magnet with the clock and dry cells.

10. Place signal magnet so that its movements are recorded on the smoked drum about one centimeter above the lower edge of the record sheet. The signal magnet should stand about one centimeter ahead of the level of the spirometer stylus.

V. The respiration recorder

1. After adjusting the spirometer stylus and signal magnet, set the respiration recorder at zero.

VI. During the run

1. Watch the kymograph, spirometer, stylus and signal magnet. Be sure your record is complete. When the stylus nears the top of the kymograph drum, water must be added to the tank. Avoid shaking the drum when adding water to tank. Admit water as the stylus starts down, i.e. at the beginning of expiration.

2. If at any time the absorbent cartridge becomes unduly hot throughout the length, or if at any time the subject shows difficulty in breathing, an analysis for CO₂ should be made and the cartridge examined. If the cartridge be caked or if CO₂ be found by analysis, the cartridge should be removed and replaced by a fresh one.

VII. After the run

1. When the experiment is ended, close the valves in the inlet and outlet pipes.

2. Immediately remove the rubber tubes and mouthpiece.

3. Scrub the mouthpiece with soap and water, using a brush.

4. Rinse the tubes in clean water.

5. Place the tubes and mouthpiece in the sterilizer to boil.

6. Place a fresh set of sterilized tubes on machine. Before placing fresh tubes on machine, wet the ends to permit of better slipping on.

7. Mouthpieces which have been properly sterilized (5 minutes at boiling point) should be placed in a designated box and covered with gauze. Do not handle sterilized mouthpieces with fingers. Use dressing forceps. The rubber tubes, when sterilized, are to be hung on nails to dry.

8. The air in the tank is then analyzed and a second sample drawn into the gas analysis apparatus for subsequent analysis.

9. Put the necessary data on the kymograph record and shellac the same. It is not necessary to wait for the gas analysis before shellacing the kymograph record. To shellac the record sheet proceed as follows:

a. Remove the smoked paper from the kymograph drum by carefully cutting through the outer sheet at the lap.

b. Grasp the smoked paper at each end and pass carefully through a shellac solution, record side up, and hang the paper up to dry.

VIII. Don'ts for machine men

1. *Don't* allow used tubes and mouthpieces to remain on machine or lie around. Sterilize them immediately as directed.

2. *Don't* fail to mop up immediately water on floor or on top of tank, if tank should overflow while being flushed.

3. *Don't* fail to keep the room clean. Unnecessary papers, etc. should be picked up off the floor in between runs.

4. *Don't* fail to have sufficient water in spirometer well before a run. The water should reach to within $\frac{1}{2}$ inch of the top of the well when the spirometer can is resting on the bottom of the well.

5. *Don't* fail to record the duration of each run on the absorbent cartridge. This is to be done immediately after a run.

LARSEN REBREATHES

Instructions are the same as for the Henderson Rebreather except in the case of flushing the machine.

1. The lower chamber is let down on its base. This should be done with the gate valve closed and the valve on the expiratory pipe open. This flushes the expiration pipe at the same time.

2. The spirometer can is removed from the well and an electric fan is turned on to blow the air from both tank and spirometer can. (In lieu of an electric fan an ordinary fan should be used vigorously for five minutes.)

3. The spirometer can is replaced and with the gate valve still closed and the valve on the inspiration pipe open, the chamber is elevated until the indicator is level with the line marked 52 liters. This flushes the inspiration pipe. In this position with the spirometer can down the rebreather contains 52 liters of air.

4. When ready for the run raise the spirometer can the desired height by elevating the lower chamber.

5. During the run when the stylus nears the top of the kymograph drum elevate the lower chamber as the stylus starts down, i.e., at the beginning of expiration.

PULSE AND BLOOD PRESSURE DETERMINATIONS

TIME OF DETERMINATIONS DURING A REBREATHING RUN

1. Preliminaries: Three readings of systolic and diastolic pressures and three pulse counts are taken as the subject is seated waiting for the rebreathing test. To avoid as much as possible the psychic and exercise effects these normals should be taken before the psychologist begins his explanation of the apparatus.

2. Systolic and diastolic pressures are taken the first minute of the run and on alternate minutes until the 17th minute from which point they are taken every minute during the remainder of the run.

3. Pulse count is begun twenty seconds after the start of the run, is counted 20 seconds, the count being multiplied by three and recorded. A similar pulse count is taken every minute during the duration of the run.

4. Recording: The rule to be followed in making the determinations is to count the pulse rate in the interval between 20 and 40 seconds on the stopwatch and to record the count on the half minute. The first count, therefore, will be recorded *on the line between 0 and 1*. The systolic and diastolic pressures should be determined in the interval between 45 and 15 seconds by the stopwatch and recorded as having been taken on the minute. These should be entered on the record sheet in the space between the lines, *the first determination in space 1*. This system of recording will make it possible for the plotter to indicate the time intervals with exactness on the chart. It is important that the exact time of the determination of the experiment be indicated on the circulation record sheet so that the man who plots the record may correctly indicate with a heavy line the time the candidate was taken off.

5. After the run: Pulse counts and blood pressure readings should be interrupted as little as possible by the termination of the run and should be taken for three minutes or longer if the return is not complete.

SUGGESTIONS TO THE PHYSIOLOGIST AS TO THE REBREATHING TEST

It is the physiologist's duty to provide reliable conditions for a rebreathing experiment. All interpretations of data and the final rating of the candidate require that the oxygen percentage at the end of the test be accurately known. Therefore, the analysis of the air in the tank at the close of the test must be exact. In order to make a reliable analysis, the gas analysis apparatus must be clean and the sample of air a true sample of the air in the tank. In taking the air sample fill the burette of gas analysis apparatus with air from tank and then expel into the room air, repeat this process three or four times then retain a sample for analysis. The pyrogalllic acid and hydroxide solutions are effective for from 50 to 100 determinations. At least two analyses should be made before a final percentage is determined.

A perfect experiment requires that the rebreathing machine be in perfect order. It is advisable to test the machine occasionally for leaks. In order to do so raise the spirometer can, then close all valves and place a weight on the spirometer can. Note during a period of 30 minutes whether the can settles any. If it does, a leak is present and must be found and corrected.

The efficiency of the Respiration Recorder depends on the proper summing of the inspiration volumes. Look it over now and then for loss of motion. The felt on the rim and back of the dial may wear so that some motion of the graduated dial is lost with each breath. This may be remedied by increasing the pressure of the two contact levers.

Physiologist is also responsible for the obtaining and interpretations of all physiological data. These data for the present include the per-minute volume of breathing, the pulse-rate and the three arterial pressures—systolic, diastolic and pulse.

It has been found that the work of the plotter should be frequently checked in order to determine whether the data are properly spaced. A misplacement of the terminal time lines and of the oxygen percentage line may result in an unfair classification of the candidate. Note whether the blood pressures are recorded on the minute and the pulse rates on the half-minute lines.

AVOIDANCE OF EXCITEMENT

It is necessary that every effort be made to avoid the occurrence of an excitement stage, at the beginning of a run, as same has a tendency to mask the reactions of the subject during the test. This can easily be done by tact on the part of the physiologist in handling the aviator, and also by the unit as a whole refraining from any chance remarks which might tend to give the subject a distorted idea of the test.

It must be borne in mind, that when an aviator presents himself for examination he knows very little of the real nature and object of the test. In most cases, he is under the impression that if he fails to make a good showing

he will be disqualified from flying. While this occasionally occurs, it might happen so seldom that the possibility of it might be disregarded entirely.

It is suggested that the physiologist, while taking the preliminary blood pressure, explain to the flier the nature of the test, laying stress upon the following points:

1. That the possibility of being disqualified as a result of the test is almost nil, the majority of men receiving a very good rating.
2. The object of the test is to safeguard the life of the aviator by determining the altitude to which he can safely go, without showing any ill effects.
3. No attempt is made to duplicate the conditions existing in the air.
4. The test is without the least danger and not followed by any ill effects.
5. The classification is likely to vary from time to time, depending upon the number of hours in the air, intensity of flying, etc.

It is further suggested that the physiologist start the run with as little ceremony as possible. It is inadvisable to count one, two, three, or use the word "go" as this has a tendency to cause the blood pressure and pulse rate to go up. The insertion of the cork or the closing of the valves can be signified by a nod of the head, and done very quietly and quickly.

By following the above much can be done to avoid an excitement stage.

DIRECTIONS TO CLINICIAN

The attention of the clinician is directed to the "General Instructions for the Conduct of Altitude Classification Tests."

The Clinician is to be present throughout the test and is primarily responsible for the subject's condition. In case the safety of the subject demands it, he should not hesitate to examine the heart frequently, especially toward the close of the test.

The Clinician will be the one to terminate the test by removing the mouthpiece or nose-clip. About four times out of five probably this will be at the instance of the psychologist who will plainly indicate as soon as his results are satisfactory. When this point has been reached the subject is probably within a short space of insensibility and the mouthpiece should be removed without delay.

The Clinician may terminate the test before the psychologist has obtained his full results if he considers that safety demands it, but such an occurrence should be infrequent if proper judgment is used, because any abnormal circulatory condition will give an early psychological effect, and it is usually safe to let the test go to this point. An exception is made in any case of cardiac arrhythmia (except sinus arrhythmia) which increases during the test. In this case the experiment should be terminated very early.

When a definite cardiac lesion can be determined it is unnecessary to prolong the test, for if the clinician's rating is "C" or "D" it is a matter of small importance whether the psychologist's rating is "A" or "B."

The indications for interference by the clinician are two: First, that he has determined a disqualifying cardiac condition; second, that the subject is on the verge of fainting. To guard against this latter the clinician should carefully watch the pulse and blood pressure record and should instruct the

observer to call his attention at once to any marked change. Blood pressure readings every minute are desirable toward the end of the test. Subjects who have had an excessive response in pulse and blood pressure, those whose hearts are evidently working too hard throughout the test should be especially carefully watched, but even in these cases it is always safe to allow the test to go on either until the psychologist is satisfied or until there are definite signs of fainting. Rapidity of pulse or moderate increase in blood pressure is not an indication for stopping the test.

The first sign of fainting will be most commonly a drop in the diastolic blood pressure, followed by a fall in systolic blood pressure and pulse rate, if the subject is not restored to fresh air. Less commonly, the first sign will be a fall in the systolic pressure or a fall in both systolic and diastolic blood pressures simultaneously. Prompt removal of the mouthpiece and nose-clip will prevent fainting in most cases. The diastolic pressure will very frequently show a gradual fall toward the end of the run but if this drop is controlled (less than 5 mm. per minute continually) it should be regarded as normal. Such a steady fall, however, demands careful watching for it may end with a sudden uncontrolled drop.

It is highly important to avoid fainting when possible (and even the cerebral type of unconsciousness) though a certain number of cases will faint in spite of the most careful watching—this may occur with great suddenness, especially when coming early in the run.

A middle ground must be taken, giving the psychologist as much opportunity as possible for his observations, and yet avoid disagreeable terminations of the test. As remarked above the psychologist should terminate the test at least four times out of five runs.

DIRECTIONS TO PSYCHOLOGIST

METHOD OF CONDUCTING A RUN

The rebreathing machine is set by the physiologist to give a standard run, which will bring the class A man to about 7 per cent of oxygen in an average time of 25 minutes. The reactor is seated before the apparatus and his normal pulse and blood pressure taken. When three readings have been taken, he is given the psychological instructions and should be allowed to read them without interruption. Do not volunteer any information unless he requests it. When he has finished the instructions, ask him if he understands them and give any explanation necessary. The instructions should be readily comprehended and any unasked for explanations may be confusing to the reactor.

When the reactor has finished the directions, the mouth-piece and nose-clip are adjusted by the machine man and at the given signal all start their watches simultaneously. In making the test care should be taken to prevent the reactor from becoming anxious or worried about the experience he is about to undergo. It is also important that instructions be given in a routine way. The conditions under which a test is given to one group or person must be identically followed in giving the same test to another individual or group. If the conditions are varied they must be varied for a definite purpose. Dif-

ferences in results may be due to the time of day at which the experiment is made, nature of instructions that precede the test, emotional attitude of participants toward the investigation, ability to comprehend what is wanted of them and their willingness to do it when understood. No test should be undertaken until the subject is perfectly clear as to what is required of him.

Do not confuse the subject by plugging in lights, motor and ammeter simultaneously. Let him react to ammeter, then ammeter and motor, then ammeter, motor and lights (or any desired order). By the end of the third minute he should be working at all three tasks.

Check the subject's normal reactions during the first three minutes of the run.

The subject's comprehension, attention and composure are rated good, fair or poor. His motor tendencies are checked:

1. Tremor, tense *or* relaxed
2. Impulsive *or* steady
3. Rapid *or* slow
4. Hesitant *or* prompt
5. Accurate *or* inaccurate

Any unusual characteristics should be added. (Apprehensive, resentful, etc.)

When the run is ended, note on the record sheet the length of run, reason for removal from machine (whether psychologist, clinician or physiologist) and final oxygen.

It is advisable to add at the bottom of the record sheet any unusual characteristics that develop during the run.

DIRECTIONS TO SUBJECT

DIRECTIONS FOR CONDUCTING PSYCHOLOGICAL TEST DURING REBREATHING EXAMINATION

Give the following instructions *after* the normal blood pressures have been taken.

INSTRUCTIONS

You have three things to do:

1. *Lights*

When a light flashes, touch with the stylus the top of the corresponding screw head. Do not touch the washer.

The upper row of lights corresponds with the upper row of contact buttons, the lower row of lights with the lower row of contact buttons.

2. *Ammeter*

Watch the ammeter and by adjusting the rheostat (using the right hand) keep the ammeter at the designated mark, which is five (5).

3. *Motor*

Keep the motor at low speed by adjusting the foot pedal. When the motor speeds up, push the pedal from whichever position in which it may be

(heel down, or toe down) into the opposite position and hold it there until the speed again increases.

Notes: (a) The lights are of first importance. If a light appears when you are reacting or about to react to the ammeter hand, react to the light first and then go back to the rheostat.

(b) When you make contact with the stylus the movement must be a "free" one neither hand nor arm should touch the board. The hand at other times may rest on the rheostat slide.

(c) If the clinician, in making his examination, interferes with your movements on the board, you may cease work until he finishes his examination.

Do your work with accuracy, neatness and promptness. Do not bang, slam or jab.

SYMBOLS AND THEIR SIGNIFICANCE

- ✓M First significant effects on voluntary coördination.
 - ♀ Fumbling; clumsy; inaccuracy in approaching targets.
 - ♀ Groping; approaching target with corrective movements. Usually a compensation for ♀
 - E Increased effort or force in applying stylus to target.
 - ⊖ Decreased effort.
 - I Impulsive or uncontrolled movements: (a) on the outward movement, to the target; (b) on the return movement.
 - S Slowing of reactive movements.
 - F Speeding of reactive movements.
- ✓A First significant effects on attention.
 - dl Distraction from lights, neglects lights.
 - ll Reactor delays so long that he touches the target after the light has gone out.
 - lll Reactor starts the movement after the light has gone out.
 - llll Reactor makes no attempt to initiate light reaction.
- dl-v Neglects lights for ammeter.
- dv Distraction from the dial; neglects to note and adjust the position of the index hand.
- dn Distraction from the noise; neglects to control the speed motor.
- /cl/ Confusion between rows of lamps but finally touches the right target.
- /c/ Confusion between columns of lamps but finally touches the right target.
- /wl/ Selects target in wrong row.
- /w/ Selects target in wrong column.
- wn Wrong shift of pedal.
- wv Wrong direction on the dial.
- ◇M Two of the symptoms E, S, I, a or b, ♀, ?, ⊖ repeatedly. In certain cases exaggeration of one.
- ◇A Two of the symptoms dl, dn, dv, dl-v, wn, wv, ll, lll, llll, /cl/, /wl/. In certain cases exaggeration of one.
- O Inefficiency. Inability to control any two of the three tasks. The reactor sometimes stares at the lights without making any attempt to touch the target, or makes merely irrelevant touches. He may

completely disregard L and N. Sometimes he develops severe tremors or jerks which render it impossible to work. Occasionally a reactor develops a unique symptom at this point.

* Breakdown. Reactor ceases to work and commences to collapse.

× Reactor taken off. Air or oxygen given him.

Y Reactor removes mouthpiece, terminating run prematurely.

ADDITIONAL SYMBOLS

〰 Tremor of the hand.

vvvvv Jerkiness of the hand.

H Swaying or drooping of the head.

T Taps button more than once.

R Rests hand or fingers while making contact.

K Keeps stylus on button after making touch.

W Strikes washer.

h Hesitation in starting or completing reactions.

PHYSIOLOGICAL RULES FOR RATING

CLASS "A"

Compensation must be maintained to 8 per cent oxygen or less.

Systolic must increase or hold to 8 per cent oxygen or less and must remain below 155 mm. throughout the greater part of the run. A brief rise above 155 mm. is allowable at the end of the run. The normal must not exceed 140 mm.

Diastolic must increase, remain on level or hold with a controlled drop to 8 per cent oxygen. A fall of 5 mm. in a minute is suggestive of a weakening of the vaso-motor control and if this rate continues or is exceeded in the next minute the fall should be considered uncontrolled. A fall of 10 mm. in the last minute is considered uncontrolled.

Pulse must increase or hold to 8 per cent oxygen and must not exceed 125 beats per minute between the fifth minute and 10 per cent oxygen.

Respiration must increase 3 liters or more.

CLASS "B"

Compensation must be maintained to 10 per cent oxygen or less.

Systolic must increase or hold to 10 per cent oxygen or less and must remain below 165 mm. throughout the greater part of the run. The normal must not exceed 150 mm.

Diastolic must increase, remain on level or hold with controlled drop to 10 per cent oxygen.

Pulse must increase or hold to 10 per cent oxygen and must not exceed 145 beats per minute between the fifth minute and 12 per cent oxygen.

Respiration must increase 1.5 liters or more.

CLASS "C"

Compensation must be maintained to 12 per cent or less.

Systolic must increase or hold to 12 per cent oxygen.

Diastolic must increase, remain on level or hold with a controlled drop to 12 per cent oxygen.

Pulse must increase or hold to 12 per cent oxygen and must not exceed 150 beats per minute between the fifth minute and 12 per cent oxygen.

Respiration may increase less than 1.5 liters.

CLASS "D"

Circulatory collapse occurs before 13 per cent oxygen. If doubt exists as to the final rating, the candidate should be given the benefit of a rerun.

TIME CORRECTION

1. If the duration of the run is 20 minutes or less, one per cent oxygen must be added to the final analysis for the purpose of rating. The actual per cent of oxygen found by analysis, however, will be used in drawing the oxygen line on the chart.

2. If the duration of the run is between 20 and 22 minutes, $\frac{1}{2}$ per cent oxygen is to be added to the final analysis for the purpose of rating.

RESPIRATION RESPONSE

To determine the respiration response for the purpose of rating, the lowest per minute volume of deciliters breathed before reaching 15 per cent oxygen is taken as the *minimum volume*. The highest per minute volume of deciliters breathed in the last three minutes of the run is taken as the *maximum volume*. The difference between the minimum volume and the maximum volume is termed the *respiration response*.

RULES FOR CLINICAL RATING

1. When the diagnosis of myocardial or valvular heart disease is made, the subject will be disqualified. No attention need be paid to sinus arrhythmia which is normal. Premature contractions are unimportant unless occurring very frequently. All other abnormal rhythms are to be unhesitatingly rejected.

2. The experiment should not in any case be prolonged beyond the point where the clinician has fully satisfied himself of an abnormal heart.

3. The clinician will not be called upon to decide on cases which compensate poorly, since they will receive a low rating from the physiologist, who will demonstrate failure of compensation long before the clinician could. The type of person, however, who because of general poor constitution fails to compensate at all (no rise in pulse, none in respiration, no change in blood pressure) should be rejected rather than given a low rating. Such cases, however should be very rarely found in the Air Service.

4. (a) If heart action impresses one as being poor—rate subject down one point, ex. from A to B.

(b) If sure of organic disease terminate run and grade D, i.e., should not fly at all.

(c) If subject goes to 8.0 per cent or less and reaction is normal—rate A.

(d) If subject goes to a point between 10 and 8 per cent O_2 and reaction is normal—rate B.

(e) If subject goes to a point between 12 and 10 per cent O_2 and reaction is normal—rate C.

(f) If the physiological rating is below "A" because of some circulatory condition, the clinical rating will never be higher than the physiological rating.

5. The heart normally reacts in the following manner: First some accentuation of both sounds during the psychic period, becoming a little quieter in action following this period. As the run continues, the rate becomes faster and both sounds somewhat accentuated until just before the germination of the run, when both sounds become fainter. If the systolic pressure holds and the diastolic pressure falls but is controlled, the first sound then is louder than the second. If there is an uncontrolled drop just short of the fainting point, the second sound disappears, the first being heard as a distinct thumping. If both systolic and diastolic pressures fall uncontrolled, no sounds are heard and the subject faints.

6. Pay a great deal of attention to color and general appearance, because these are sometimes the most valuable signs in determining whether or not the subject should be removed by the clinician.

7. Our experience is that there is little real heart strain during the ordinary run, and the psychologist should remove the subject in about four out of five cases.

PSYCHOLOGY

RULES FOR RATING

The following six factors are considered in rating:

- Time at which the motor "crotch" occurs.
- Time at which the attention crotch occurs.
- Time at which the motor "diamond" occurs.
- Time at which the attention diamond occurs.
- Final oxygen.
- Duration of run.

Assume 15 minutes as the standard time for the appearance of the crotches. If the crotch appears earlier than the 15th minute, debit $\frac{1}{2}$ point for each minute. If the crotch appears later than the 15th minute, credit $\frac{1}{2}$ point for each minute.

Assume 25 minutes as the standard time for the appearance of both diamonds. If the diamond appears before the 25th minute, debit 1 point for each minute; if it appears later than the 25th minute credit 1 point for each minute.

Take 25 minutes as the standard duration of the run. Debit or credit 1 point for each minute as above.

Assume as a standard of altitude 7 per cent of oxygen. Debit or credit 1 point for each 0.1 per cent.

Add the debits and credits and assign to class as follows:

N.....	to.....	0	Class A
-0.5.....	to.....	-12	Class A-
-0.12.5.....	to.....	-30	Class B
-0.30.5.....	to.....	-N	Class C

In scoring time, more than 30 seconds are counted as a minute.

In the event that one or both crotches or diamonds have not occurred at the time of the termination of the run, they are rated as coming at the end of the run but are not written on the record.

If the subject fails to reach 8 per cent oxygen in a run of less than 30 minutes, he may not be assigned a grade above B. For runs reaching a low per cent of oxygen (below 7 per cent) in less than 22 minutes, discretion may be exercised for early appearance of symbols.

If a reactor is removed by the clinician, and his rating is B (or C) it is written B or higher (or C or higher). If his rating is A, it is entered as such.

TEST OF AVIATOR UNDER LOW OXYGEN TENSION

(REBREATHER EXAMINATION)

Rating.....

(Place)..... (Date).....

(Name.)

(Rank and organization.)

(Flying status.)

(Age.)

Pers. Hist., Educ'n, etc.

Experience in athletics (dates)

How recently or constantly have you been in hard condition (training)?

Are you so now?

Experience in aviation hrs. to Max. alt. ft. for min.

Symptoms at altitudes

Present condition (give details of present health)

Time of last meal Appetite Temperature Weight Digestion

Are you feeling fit to-day? (Loss of sleep, dissipation, nervous tension, overwork, indisposition, eye strain, indigestion, cold, etc.)

Other remarks

General build and appearance (note especially cyanosis, mottling, coldness of extremities, pallor, sweat, etc.)

Heart: Apex felt (point farthest out) in sp. cm. to L. of Mid.

L. Border (dullness) in 6th sp. cm.; 5th sp. cm.; 4th sp. cm.; 3d sp. cm. to L. of Mid.

Upper border R. border cm. to R. of Mid.

After 5 min. reclining: B. P.; pulse On standing 2 minutes: B. P.; pulse

After standard exercise: Pulse at once; 60 sec.; 90 sec.; 120 sec.

C. E. T. score

Blood vessels

General impression, psychological: Comprehension Attention Composure Relaxed

Tremulous Tense Impulsive Steady Rapid Slow

Prompt Hesitant Accurate Inaccurate Restless Apprehensive

Personality study (neuropsychiatry)

SUMMARY OF OBSERVATIONS DURING LOW-TENSION TESTS.

Duration of test minutes seconds. Taken off by

Phys. cond. during test

Exact condition at close of test

Recovery

Remarks

Physiol. Clin. Psy.

On machine On Bl. Pr. O₂%: Start, finish

Clinical:

Physiological:

Psychological:

RECOMMENDATION OF BOARD AS TO FITNESS OF AVIATOR.

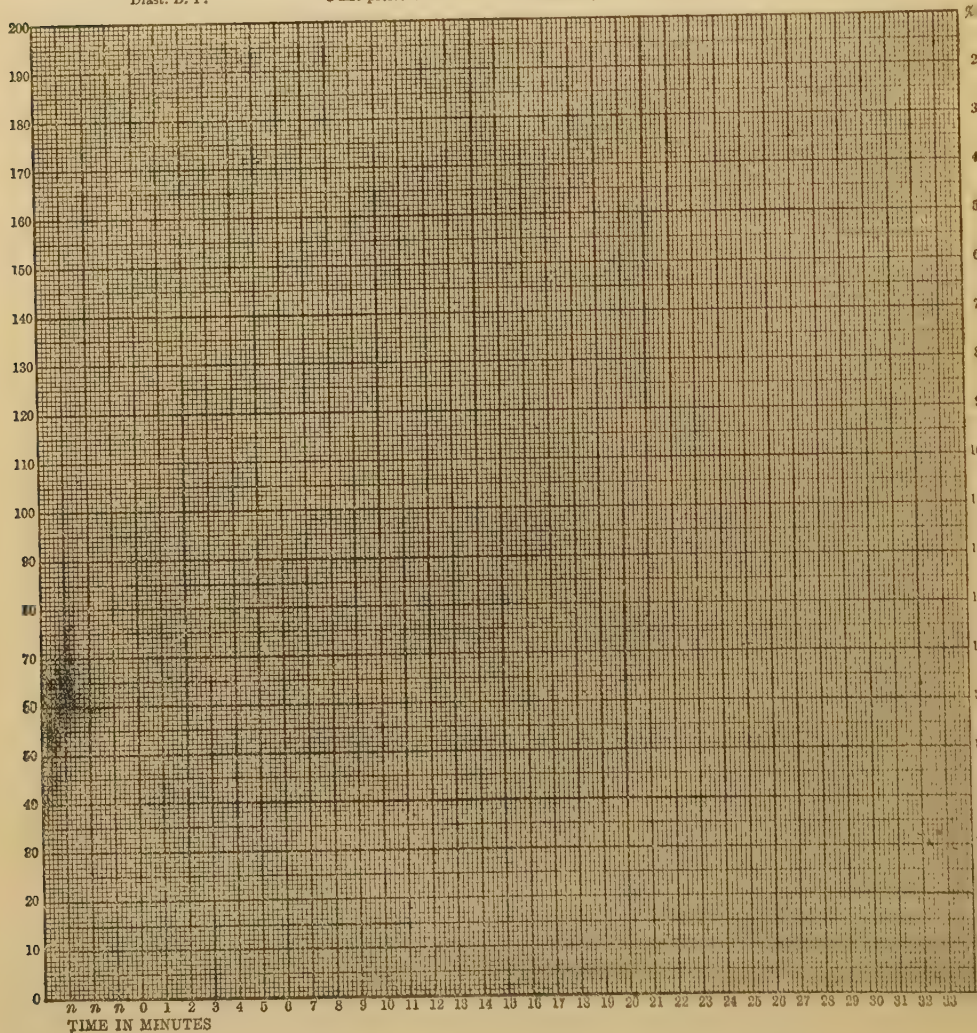
(Signed) _____ Clinician.
 _____ Physiologist.
 _____ Psychologist.

LEGEND: O₂%
 Diast. B. P.

Pulse
 Pulse pressure

Resp. in decil. per min.
 Plotted by

Syst. B. P.



PSYCHOLOGICAL RECORD—OXYGEN DEFICIENCY

Reactor _____ Date _____ Time _____

Station _____ Psychol. _____ No. _____

Phys. _____ Cl. _____ Vas. _____ Oph. _____

	NORMAL	Tremor	Slow	RATING
		Tense	Hesitant	
Comprehension _____		Impulsive	Accurate	
Composure _____		Steady	Inaccurate	
Attention _____		Rapid	Restless	
		Prompt		

MIN.	OBSERVATION	SYM.	O ₂	MIN.	OBSERVATION	SYM.	O ₂
0				16			
1				17			
2				18			
3				19			
4				20			
5				21			
6				22			
7				23			
8				24			
9				25			
10				26			
11				27			
12				28			
13				29			
14				30			
15				Reason for X. _____			

RESPIRATION RECORD

Name _____

Organization _____

Rank _____

Date _____

Field _____

Observer _____

Minute	Reading	Deciliters	Minute	Reading	Deciliters
1			19		
2			20		
3			21		
4			22		
5			23		
6			24		
7			25		
8			26		
9			27		
10			28		
11			29		
12			30		
13			31		
14			32		
15			33		
16			34		
17			35		
18			36		

PULSE RECORD

Name _____ Date _____ Observer _____

Place _____

Time	Systolic	Diastolic	Pulse	Time	Systolic	Diastolic	Pulse
N.				26			
N.				27			
N.				28			
O.				29			
1				30			
2				31			
3				32			
4				33			
5				34			
6				35			
7				36			
8				37			
9				38			
10				39			
11				40			
12				41			
13				42			
14				43			
15				44			
16				45			
17				46			
18				47			
19				48			
20				49			
21				50			
22				51			
23				52			
24				53			
25				54			

PHYSICAL EXAMINATION FOR FLYING.

(See Section II, AR 40-110)

(Last name.) _____ (First name.) _____ (Middle initial.) _____ Age _____

(Rank.) _____ (Regiment or branch.) _____

Purpose of the examination* _____

EYE EXAMINATION.

1. Visual acuity: R. E. _____ L. E. _____
2. Depth perception at 6 meters _____ mm.
3. Maddox Rod Screen Test at 6 meters:
Eso. _____ Exo. _____ R. H. _____ L. H. _____
4. Maddox Rod Screen Test at 33 cm.:
Eso. _____ Exo. _____
5. Prism divergence _____
6. Associated parallel movements _____
Tangent curtain diagnosis _____
Nystagmus _____
7. Inspection _____
Pupils: Equality _____; shape _____; reaction _____
8. Accommodation: R. E. _____ D. L. E. _____ D.
9. Angle of convergence: PcB _____ mm. Pd _____ mm. Angle _____
10. Retinal sensitivity _____
11. Central color vision. R. E. _____ L. E. _____
12. Field of vision. Form: R. E. _____ L. E. _____
Color: R. E. _____ L. E. _____
13. Refraction (Homatropine). Tension _____
R. E. { Reads 20/20 with _____
True correction _____ L. E. { Reads 20/20 with _____
True correction _____
14. Ophthalmoscopic examination:
R. E. _____
L. E. _____

EAR EXAMINATION.

15. History of ear trouble:
 - (a) Ever have ringing or buzzing in either ear, earache, discharge or mastoiditis? _____
 - (b) Ever have attacks of dizziness from any cause? _____
 - (c) Ever had a severe injury to head? _____
16. (a) Appearance of external auditory canal: Right _____ Left _____
(b) Appearance of membrani tympani: Right _____ Left _____
(c) Hearing:
Right ear, watch _____/40; coin click _____/20; voice _____/20.
Left ear, watch _____/40; coin click _____/20; voice _____/20.

*Semiannual, appointment as cadet, commission in Air Service, commission in Air Service Reserve Corps, transfer to Air Service, or any other special purpose.

NASO-PHARYNX.

17. Condition of nares (if obstructed, state degree, character, and cause):

Right.....
Left.....

18. Condition of tonsils and history of attacks of tonsillitis:

Right.....
Left.....

19. Presence of adenoids.....

20. Condition of eustachian tubes (if obstructed, state character and degree) after politizerization or per catheter.....

EQUILIBRIUM.

21. Equilibrium (vestibular), head tilted forward 30 degrees. Eyes closed. Rotation nystagmus normal 26 seconds, a variation of 10 seconds allowable:

(a) Right: Applicant to be turned toward his right, 10 turns in exactly 20 seconds, horizontal nystagmus to left for seconds..

Left: Applicant to be turned toward his left, 10 turns in exactly 20 seconds, horizontal nystagmus to right for seconds.

- (b) Pointing tests:

- (1) Before turning:

Right arm, left arm

- (2) After turning 10 times in 10 seconds to right:

Right arm, left arm

- (3) After turning 10 times in 10 seconds to left:

Right arm, left arm

- (c) Falling tests:

(1) Turn to right, 5 turns in 10 seconds—Falls to.....

(2) Turn to left, 5 turns in 10 seconds—Falls to.....

22. Caloric Test when 21 is unsatisfactory.

Douche right ear.

Amplitude of eye movements.

After Min. Sec.

Nystagmus.

Vertigo.

Past-pointing.

Falling.

Head back.

Amplitude of eye movements.

Douche left ear.

Amplitude of eye movements.

After Min. Sec.

Nystagmus.

Vertigo.

Past-pointing.

Falling.

Head back.

Amplitude of eye movements.

GENERAL EXAMINATION.

23. Previous medical history.	DATE.	DURATION.	COMPLICATION.
(a) None.....			
(b) Tonsillitis.....			
(c) Scarlet fever.....			
(d) Measles.....			
(e) Mumps.....			
(f) Pneumonia.....			
(g) Typhoid.....			
(h) Lues.....			
(i) Gonorrhoea (acute).....			
(j) Rheumatism, No. attacks.....			
(k) Asthma, No. attacks.....			
(l) Hay fever, No. attacks.....			
(m) Malaria, No. attacks.....			
(n) Injuries.....			
(o)			

24. General build and appearance

25. Temperature Height inches. Weight pounds.

26. Chest measurement: Expiration inches. Inspiration inches.
 Waist measurement at umbilicus inches.

27. Respiratory

28. Bones and joints.....

29. Skin.....

30. Vascular system Schneider Index Rating

- (a) Pulse: Rate (sitting) per minute; quality
- (b) Condition of arteries.....
- (c) Condition of veins.....
- (d) Blood pressure (sitting): Systolic Diastolic
- (e) Heart
- (1) Murmurs
- (2) Arrhythmias
- (f) Hemorrhoids

31. Digestive system

	Right.	Left.	
Missing teeth.	Upper, 8, 7, 6, 5, 4, 3, 2, 1	1, 2, 3, 4, 5, 6, 7, 8	(Strike out those that are missing.)
	Lower, 8, 7, 6, 5, 4, 3, 2, 1	1, 2, 3, 4, 5, 6, 7, 8	

32. Hernia

33. Genito-urinary system

34. Urinalysis:

Specific gravity

Reaction.....

Casts.....

Albumen

Sugar.....

NEURO-PSYCHIATRIC EXAMINATION.

35. Family history of insanity or other nervous diseases
36. Tobacco Alcohol Drugs
37. Syphilis Headaches Stammering
 Epilepsy Dizziness Insomnia
 Enuresis Fainting Somnambulism
 Dreams
38. Memory Will grasp Phobias
 Worries
 Anxieties
 Conflicts
 Complexes
 Irritability Apathy Elation
 Depression
39. Pupillary reactions
 Secondary dilatation: (Normal) (Prolonged)
40. Station 41. Patellar reflexes
42. Tic 43. Tremor
44. Psychomotor tension: Peripheral circulation:
 Normal Normal
 Increased Relaxed
 Decreased

RESULT OF THE EXAMINATION.

45. Is the candidate physically qualified for flying duty? If not, reason for disqualification

(Place.)

(Date.)

3-8218

Medical Corps, U. S. Army.

PHYSICAL EXAMINATION FOR FLYING.

"INSTRUCTIONS."

1. A record of the examination, in triplicate, will be made on this form. Two copies will be forwarded via the Commanding Officer to the Bureau of Medicine and Surgery, Navy Department, and the third copy retained by the flight surgeon at the station of the candidate. Upon receipt of the two copies of this form, they will be approved or disapproved by the Bureau of Medicine and Surgery, one copy retained for permanent file, and one copy returned to the station from which received.

2. Upon receipt back at the station of the copy of this form, the action of the Bureau of Medicine and Surgery contained thereon will be transcribed to the retained copy and the same certified as a "true copy."

3. Whenever an individual is transferred to another station, the copy of this form with the action certified thereon, as provided in paragraph 1 above, will be forwarded to the flight surgeon of the new station. The other copy of this form will be retained at the station for permanent file.

(Surname.) (Christian names.) (Rank or rate.) U. S. N. Age..... yrs. mos.

This examination is: Flying status
(Annual, original, deferred, special, etc.) (E/A, L/A, Pilot, Observer, etc.)

GENERAL EXAMINATION.

1.	Previous medical history.	Date.	Duration.	Complication.
(a)				
(b)				
(c)				
(d)				
(e)				
(f)				

2. General build and appearance

3. Temperature Height inches. Weight pounds.

4. Chest measurement: Expiration inches. Inspiration inches. Abdominal measurement at umbilicus inches.

5. Respiratory

6. Bones and joints

7. Skin

8. Vascular system

(a) Condition of arteries

(b) Condition of veins Hemorrhoids

(c) Pulse rate per minute: Prone, standing, after exercise

(d) Blood pressure: Prone: Syst.; diast. Standing: Syst.; diast.

(e) Heart

(1) Murmurs

(2) Arrhythmias

(f) Circulatory efficiency rating

9. Digestive system

Upper 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, } Strike out missing teeth.

Lower 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32. }

10. Hernia

11. Genito-urinary system

12. Uroanalysis:

Specific gravity

Reaction

Casts

Sugar

Albumen

NEUROPSYCHIATRIC EXAMINATION.

13. Family history
14. Personal history and habits
15. Fainting..... Headaches..... Dizziness.....
 Somnambulism..... Insomnia..... Dreams.....
 Enuresis..... Stammering.....
16. Memory..... Will grasp..... Phobias.....
 Worries.....
 Anxieties.....
 Conflicts.....
 Complexes.....
 Depression..... Apathy..... Elation.....
17. Station..... Patellar reflexes.....
18. Tic..... Tremor.....
19. Psychomotor tension..... Peripheral circulation.....
20. Impression

EYE EXAMINATION.

21. Visual acuity: R. E. L. E.
22. Depth perception at 6 meters mm.
23. Maddox Rod Screen Test at 6 meters:
 Eso. D. Exo. D. R. H. D. L. H. D.
24. Maddox Rod Screen Test at 33 cm.:
 Eso. D. Exo. D.
25. Prism divergence D.
26. Associated parallel movements
 Tangent curtain diagnosis
 (In all cases of muscular imbalance.)
- Nystagmus
27. Inspection
- Pupils: Equality....., shape.....; reaction.....
28. Accommodation: R. E. D. L. E. D.
29. Angle of convergence: PcB mm. Pd. mm. Angle
30. Central color vision: R. E. L. E.
31. Field of vision. Form: R. E. L. E.
 Color: R. E. L. E.
- Refraction (Homatropine). Tension.....
 R. E.—Reads 20/20 with
 True correction
- L. E.—Reads 20/20 with
 True correction
33. Ophthalmoscopic examination
- R. E.
- L. E.

EAR EXAMINATION.

34. History of ear trouble:

(a) Ringing or buzzing, carache, or discharge.....

(b) Severe injuries to head.....

35. (c) External auditory canal: Right.....

Left......

(b) Membrani tympani: Right.....

Left......

(c) Hearing:

Right ear, watch /40; coin click /20; whispered voice /15.

Left ear, watch /40; coin click /20; whispered voice /15.

NASOPHARYNX.

36. Condition of nares:

Right.....

Left.....

37. Condition of tonsils and history of attacks of tonsillitis:

Right.....

Left.....

38. Presence of adenoids.....

39. Condition of eustachian tubes after politzerization.....

EQUILIBRIUM.

40. Equilibrium (vestibular), head tilted forward 30 degrees. Eyes closed. Rotation nystagmus normal 26 seconds, a variation of 10 seconds above and 12 seconds below allowable.

(a) *Right:* Applicant to be turned toward his right, 10 turns in exactly 20 seconds, horizontal nystagmus to left for.....seconds.

Left: Applicant to be turned toward his left, 10 turns in exactly 20 seconds, horizontal nystagmus to right for.....seconds.

(b) Falling tests:

(1) Turn to right, 5 turns in 10 seconds—Falls to.....

(2) Turn to left, 5 turns in 10 seconds—Falls to.....

(c) Caloric test when (b) is unsatisfactory. Water at 75° F. Head erect.

Douche right ear:

Douche left ear:

Nystagmus after min. sec.

Nystagmus after min. sec.

Duration..... min. sec.

Duration min. sec.

RESULT OF EXAMINATION.

41. Defects.....

42. Is candidate qualified for:

Duty involving flying?.....

Duty as pilot?.....

Aviation training?.....

43. Recommendation of board.....

(Place.)

Medical Corps, U. S. Navy.

Medical Corps, U. S. Navy.

(Date.)

Medical Corps, U. S. Navy.

{Attention is invited to Section 5, Paragraph 137 (10) U. S. N. Regulations 1920.)

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